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The Cognitive Mechanisms and Social Consequences of Imitation

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Abstract

When interacting, people imitate each other. This tendency is truly ubiquitous and occurs in many different situations and behaviours. But what causes it? Several mechanisms have been proposed to contribute to imitation. In this thesis, I focus on three candidate mechanisms: simulation, temporal adaptation, and the goal to affiliate with others. I start by discussing different imitative behaviours, and reviewing the evidence that imitation might at times emerge spontaneously. I also review the evidence suggesting that the three candidate mechanisms might be involved in such emergent imitation. Then, I present three sets of experiments.

In the first set, I investigate the role of simulation in language processing. In three experiments, I test the hypothesis that comprehenders use their language production system to simulate their interlocutor, which in turn facilitates their ability to predict the next word they will see or hear. I manipulate whether participants read the sentences silently or aloud and measure their ability to predict the final word of a sentence. My results demonstrate that prediction is enhanced when people use their production system during reading aloud. This gives some credence to the idea that simulation is routinely engaged in language processing, which in turn opens up a possibility that it may contribute to linguistic imitation.

In the second set of experiments, I investigate whether temporal adaptation leads agents to imitate features of their partner's actions. In three experiments, I test this by manipulating the partner's response speed and the information about the partner's actions. I show that agents imitate response speed when they are able to observe the partner. Moreover, they adapt to the specific temporal pattern of their partner's actions. These findings provide evidence for the engagement of the temporal adaptation mechanism during motor interactions, and for its involvement in imitation.

In the third set of experiments, I turn to the hypothesis that people engage in linguistic imitation because they want to harness the social benefits it brings. I investigate a key assumption of this hypothesis: that imitation has positive consequences for the social interaction. In three experiments, I manipulate whether participants' word choice is imitated or counter-imitated by their conversational partner and measure how it affects the participants' evaluation of the

interaction and the partner, and their willingness to cooperate with the partner. I find evidence that linguistic imitation has positive social consequences. These results are consonant with the claim that imitation is motivated by the goal to affiliate and foster social relations.

Taken together, these findings suggest that imitation might occur both in motor actions and language, and that it might have diverse causes. My work on language suggests that the tendency to linguistically imitate others could both result from the simulation mechanism, and be motivated by the goal to affiliate. My work on motor actions shows that automatic temporal adaptation contributes to emergent imitation during interactions. This research is conducive to the greater aim of cross-examining the currently known mechanisms of imitation.

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Declaration

I declare that this thesis has been composed by myself and that the research reported here has been conducted by myself unless otherwise indicated. This work has not been submitted for any other degree or professional qualification.

Jarosław Roman Lelonkiewicz

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Introduction

“It should be kept in mind that an imitative act might be performed quite unthinkingly, as when a man in the mob shouts what the other shout or clap when others clap.”

(Thorndike, 1911, p. 79)

People imitate each other. Once noticed, this fascinating tendency is impossible to miss. People copy a wide variety of behaviours, including actions and words, gestures and accents, mannerisms and sayings. Moreover, they engage in imitation in many different situations, from a face-to-face interaction to a phone conversation, and from merely observing others to being engaged in a joint action with a whole crowd. But why do they do it? The answer to this question has proved to be elusive. Despite over a century of continuous research efforts, arguably none of the existing theoretical accounts is able to explain why people engage in imitation in all its different forms, and in all the different contexts. This might be because imitation does not lend itself to our usual explanation of human behaviour, i.e. the conscious will to carry out an action. Indeed, imitation often occurs unintentionally, and independent of the conscious goals an individual might have.

So if not an act of will, then what pushes people to imitate each other? Several candidate mechanisms have been proposed to account for spontaneous imitation. In this thesis, I focus on three such mechanisms, i.e. simulation, temporal adaptation, and the unconscious goal to affiliate with others. However, each of them is associated with a distinct theoretical approach. Moreover, evidence for each mechanism tends to focus on a single instance of spontaneous imitation, and generally does not extend to its other forms. This led to a situation where psychological research on imitation, despite its long history, is unable to tell us whether the different forms of imitation can be accounted for by a single or multiple mechanisms.

In this thesis, I argue that our understanding of imitation could be advanced by a systematic cross-examination of the existing candidate mechanisms. Specifically, each mechanism should be tested with regard to a type of imitation that has not been previously considered by the research that has been used to investigate this mechanism. This would allow to identify the possible areas of overlap between the candidate mechanisms, ultimately helping to construct

better models of imitation. In the following empirical chapters of this thesis, I present three sets of experiments that contribute to such cross-examination.

The first set of experiments asks whether the simulation mechanism could be responsible for the instances of imitation in language. Simulation has been widely evidenced in relation to motor action, and the existing research suggests that it might be involved in the automatic tendency to imitate the observed movements. However, the idea that people engage in simulation also when perceiving language is relatively new and unexplored. Should simulation be routinely activated in language processing, it would make it a likely candidate for explaining the linguistic imitation that naturally occurs in dialogue.

The second set of studies investigates the possibility that some instances of imitation result from an automatic tendency to temporally adapt to others. People have been shown to readily adjust the rhythm of their own actions to the rhythm of the actions around them. However, most of the evidence for this mechanism comes from studies looking at continuous rhythmic actions. In the second set of studies, I ask whether temporal adaptation could occur also for discrete non-rhythmic actions, and whether it could contribute to imitation in interactions involving such actions.

In the third, and last, set of experiments presented in this thesis, I ask whether spontaneous imitation of language could be motivated by an unconscious goal to affiliate with others. Research on behavioural mimicry have demonstrated that imitation has various positive consequences, and suggested that people use as an unconscious tool for creating affiliation between people. But crucially, evidence for this does not extend to language. To bridge this gap, the third set of experiments investigates whether linguistic imitation could also bring about positive social consequences.

I would like to close this brief introduction by suggesting some reasons for why we need psychological research on imitation. Many excellent thinkers committed their time to researching imitation, including Adam Smith (1759), Edward Thorndike (1911), Gordon Allport (1968), Margaret Mead (1968), and Charles Darwin (1871). This is because imitation is much more than just another peculiarity of human behaviour. In fact, it is intimately related to many critical aspects of our functioning. For example, imitation plays an important role in

one of the most impressive feats of our species, i.e. social learning. The ability to imitate the actions performed by others allows individuals to acquire numerous complex skills without the need to reinvent them (e.g., writing, driving), and as such is likely to be one of the key factors in our evolutionary success. Moreover, imitation is also an important part of our social lives. Research in social psychology suggests that imitating others makes us more likable and encourages the people around us to act in a more cooperative way. Thus, imitation might be one of the behaviours that brings us together and helps to maintain positive relations with others.

Finally, imitation results from certain cognitive mechanisms. Crucially, these mechanisms are likely to be routinely engaged across different contexts and situations, and therefore might influence our thoughts and actions more generally. Thus, uncovering the mechanisms responsible for imitation promises to also uncover the inner workings of the mind. Perhaps it was this promise that lured so many to investigating imitation.

Chapter 1

The Cognitive Mechanisms and Social Consequences of Imitation: A Review

1 CHAPTER SUMMARY

In the first part of this chapter, I review the research on imitation. I start by presenting evidence that people coordinate their behaviour with each other, and that this can lead to imitation. I then review different types of imitative behaviour, and discuss the theoretical accounts that attempted to capture and describe the diversity of imitation. Next, I propose a definition of imitation that can help to avoid some of the obscurities that currently exist in the literature, and that I will use throughout this thesis. I then specify the imitative behaviours that will be considered in this thesis, i.e. linguistic imitation and imitation of motor actions.

In the second part of this chapter, I present three mechanisms that may promote these behaviours: simulation, temporal adaptation, and the unconscious goal to affiliate. I review the existing evidence for their role in shaping social behaviour. I further argue that psychological research on imitation can be advanced by testing each of these mechanisms with regards to behaviours that have previously been attributed to other mechanisms. Specifically, simulation has been widely tested with respect the motor action domain, but could be extended to language. Temporal adaptation has been investigated with respect to continuous rhythmic actions, but could be extended to discrete non-rhythmic actions. The unconscious goal to affiliate has been used to explain behavioural mimicry, but could also be applied to imitation of language. In the following empirical chapters, I present experiments that contribute to a cross-examination of these mechanisms. Thus, the aim of this review is to establish a theoretical context for these experiments.

2 PLANNED AND EMERGENT COORDINATION IN SOCIAL INTERACTIONS

Many things we do, we do with others. Whether it's a quick chat with a friend, a game of tennis, or paying at the shop counter, numerous social activities require us to smoothly

coordinate our actions with those of other people. And because we spend most of our lives in proximity of others, social coordination is reflected in a rich repertoire of behaviours.

Two general types of social coordination have been proposed in the literature. First, coordination can be planned and involve some form of conscious, intentional goal pursuit (Knoblich, Butterfill, & Sebanz, 2011). In such cases, each of the interacting agents forms a mental representation of their own actions, and of the actions of the other. Critically, this task representation is shared by both agents (Sebanz, Bekkering, & Knoblich, 2006). What exactly is being represented differs between the particular instances of coordination (see Vesper, Butterfill, Knoblich, & Sebanz, 2010). Typically agents share an action plan specifying various features of the action (e.g., spatial, temporal) and its outcome, but may also share perceptions, knowledge, goals and intentions (Knoblich et al., 2011). For example, to play a match of tennis two friends must share a goal to engage in the game, both know the rules, intend to follow them and assume that the other shares this intention. Moreover, while playing the game, each of them must plan their moves in relation to what they expect their partner to do.

Strikingly, coordination can also emerge independently of conscious goals, plans and intentions (Knoblich et al., 2011). In many social settings, agents find themselves closely coordinating their actions, despite the fact they have no intention to do so. For instance, audiences in theatres fall into the same clapping rhythm (Neda, Ravasz, Brechte, Vicsek, & Barabasi, 2000), people walking next to each other synchronise their footsteps (Van Ulzen, Lamoth, Daffertshofer, Semin, & Beek, 2008), and speakers engaged in a conversation adopt each other's body sway (Shockley, Santana, & Fowler, 2003). Language use also provides examples of such emergent coordination. In conversation, speakers align on the use of particular words (Brennan & Clark, 1996) and syntax (Branigan, Pickering, & Cleland, 2000), or adopt partner's speech rate (Webb, 1969) and accent (Giles, Coupland, & Coupland 1991). Arguably, they often do so with no explicit goal that would necessitate it. Emergent coordination is assumed to result from a number of automatic mechanisms that promote spontaneous self-organisation of agents' behaviours, i.e. entrainment, common affordances, perception–action matching, and simulation (Knoblich et al., 2011). In this view, the tendency to coordinate resembles the gravitational pull, bringing the agents into a common orbit of a shared behavioural state (Marsh, Richardson, & Schmidt, 2009).

2.1 The Link between Coordination and Imitating Others

In the process of coordination, the behaviours of the interacting agents become non-random, patterned, or synchronised in both timing and form (Bernieri & Rosenthal, 1991). Most importantly, this might lead them to effectively imitate each other's behaviour. For example, an audience who is coordinated to the point of clapping in unison consists of multiple individuals who imitate each other's clapping rhythm. Similarly, conversational partners who coordinate on their word use need to continuously imitate each other's lexical choices.

Given that many well-coordinated social interactions involve imitation, I propose that imitative behaviours may arise from the same mechanisms that contribute to coordination. Specifically, I consider two cognitive mechanisms that have been argued to result in emergent coordination, i.e. simulation and temporal adaptation (Knoblich et al., 2011). I argue that these mechanisms are routinely and involuntarily engaged in social interactions, and therefore may lead agents to spontaneously imitate each other. Moreover, imitative behaviours can also be motivated by the unconscious goal to affiliate with others, which has been shown to play an important role in promoting social coordination (Lakin, Jefferis, Cheng, & Chartrand, 2003). I argue that agents are driven by a desire to maintain positive relations with others, and that they may automatically engage in imitation because of its positive consequences for the interaction with another. These mechanisms are discussed in more detail later in this chapter. But first, in the next sections I review the evidence that people engage in a diverse range of imitative behaviours, i.e., synchrony, emotional contagion, imitative learning, overimitation, mimicry, linguistic imitation, and automatic imitation.

3 DIFFERENT TYPES OF IMITATIVE BEHAVIOUR

It seems easy to recognise imitation when we see it, and yet there is no consensus in the literature on what exactly is imitation. In fact, prevailing inconsistency in defining imitation frustrated researchers already over a century ago (e.g., Morgan, 1900). Despite over a century of efforts, imitation continues to be defined in different ways, investigated under different theoretical banners, using different methodologies, and described with sometimes conflicting terminology (Heyes, 1996). This might be because imitation is not a single behaviour, but rather a rich collection of different imitative behaviours. The manifold character of imitation

has been recognised at least since Darwin, and inspired numerous accounts that vastly differed from one author to another (for reviews, see Bavelas, Black, Lemery, & Mullett, 1987; Galef, 2013; Zentall, 2006). The following sections review the wide range of behaviours that have been studied and interpreted in the imitation literature. Note, that although these behaviours have often been investigated within different theoretical frameworks, they are not always entirely discrete.

3.1 Synchrony

Close coordination of behaviours can sometimes manifest itself in a phenomenon known as synchrony. To synchronise actions means to engage in them at the same time, simultaneously. For example, musicians performing a piece might play different parts in synchrony in order to create a beautiful harmony, or rowing crews might aim to stroke at once to achieve better movement efficiency. Such cases of synchrony are a manifestation of planned coordination. Deliberate synchronisation of actions is in itself a fascinating phenomenon and has attracted considerable attention from researchers studying musical performance and those investigating human interactions from the dynamic systems perspective (for reviews, see Repp, 2005; Repp & Su, 2013; Schmidt & Richardson, 2008). Perhaps even more interesting is the fact that people can fall into synchrony without any intention to do so. For example, a person listening in a conversation may unintentionally synchronise their body movements with the speaker's rhythm of speech (Condon & Ogston, 1966; Hadar, Steiner, & Rose, 1985). Similarly, both the listener and the speaker might align on a common pattern of body sway (Fowler, Richardson, Marsh, & Shockley, 2008). Other types of actions have also been shown to lend themselves to spontaneous synchrony, including walking (van Ulzen, Lamothe, Daffertshafer, Semin, & Beek, 2008), rocking in rocking chairs (Richardson, Marsh, Isenhowe, Goodman, & Schmidt, 2007), and swinging legs (Schmidt, Carello, & Turvey, 1990) or pendulums (Schmidt & O'Brien, 1997). Note that synchrony can bind different actions, such as in the case of musicians synchronising their parts, or same actions, as in the example with the rowing crew. Crucially, to identify such coordination as synchrony, actions must be temporally overlapping. Despite the rich literature documenting synchrony, relatively few studies investigated its underlying mechanisms. Automatic temporal adaptation (i.e. entrainment and

phase correction response) has been most often evoked to explain spontaneous synchrony. This mechanism will be discussed later in this thesis.

3.2 Emotional Contagion

Anyone who has ever travelled on a plane most likely recognises this fact: babies start crying once they hear others babies cry. This is an example of a fascinating phenomenon known as emotional contagion. People of all ages show a tendency to reflect the feelings of the individuals around them. Emotional contagion occurs with many different emotions, both positive and negative (for a review, see Hatfield, Carpenter, & Rapson, 2014). For instance, interacting with somebody who is sad might lead to an increased feeling of sadness (Howes, Hokanson, & Lowenstein, 1985). In one study, participants spoke over the phone with a person who was, unbeknownst to them, either depressed or non-depressed. Those who interacted with a depressed person reported feeling more depressed after the conversation, as compared to those interacting with a non-depressed person (Coyne, 1976). Other research has found that other emotions like loneliness (Cacioppo, Fowler, & Christakis, 2009; Cristakis & Fowler, 2011) or happiness (Christakis & Fowler, 2011; Hill, Rand, Nowak, & Christakis, 2010) are also subject to contagion. Interestingly, emotional contagion can also occur beyond the dyad. Historical, anthropological and sociological accounts suggest that individuals immersed in groups or crowds can fall into the same emotional state of joy, anger, or fear (for a review, see Hatfield et al., 2014). According to a psychological account of emotional contagion, converging on an emotional state is a consequence of physically imitating others (Hatfield, Rapson, & Le, 2009). When interacting, people copy the behavioural expression of emotions experienced by another (i.e., facial, vocal, and postural expression). The perceptual feedback from the imitated behaviours is then automatically decoded to identify the underlying emotions, which in turn induces a matching emotional state in the imitator (see also Hatfield, Cacioppo, & Rapson, 1993).

3.3 Linguistic Imitation

Having a conversation seems effortless, but in fact talking with another person requires speakers to continuously coordinate what, when, and how they say. In some cases, this leads

them to spontaneously imitate each other's language. Research in psychology and sociolinguistics has found evidence for such imitation with regards to different aspects of language. For example, Pardo (2006) showed that speakers in a conversation imitate their partner's pronunciation. Speakers' pronunciation of several target words was recorded before, during, and after they performed a conversational task with a partner. Interestingly, speakers' pronunciation during the task was found to be more similar to their partner's than to their own pronunciation before or after the task, suggesting that they imitated their partner during the conversation. People imitate also other vocal characteristics, including accent (Giles et al., 1991), voice pitch (Gregory & Webster, 1996), and tone of voice (Smith-Genthôs, Reich, Lakin, & de Calvo, 2015), and copy temporal features like speech rate (Webb, 1969), and timing and duration of pauses (Cappella & Planalp, 1981). In addition, studies found that speakers sometimes imitate sentence structure (Bock, 1987; Branigan, Pickering, & Cleland, 2000; Levelt & Kelter 1982; Weatherholtz, Campbell-Kibler, & Jaeger, 2014), linguistic style (Ireland & Pennebaker, 2010; Niederhoffer & Pennebaker, 2002), and word choice (Brennan & Clark, 1996; Branigan, Pickering, Pearson, & Mclean, 2010). For example, Branigan, Pickering, Pearson, McLean, and Brown (2011) demonstrated that people spontaneously imitate the word choice of their conversational partner, and they do so even if their partner uses an unusual, disfavoured word. This fascinating effect has been shown both for spoken and text-based conversations, in children as well as adults (Branigan, Tosi, & Gillespie-Smith, 2016; Garrod & Clark, 1993). In psychology of language, these findings have been explained by automatic priming mechanisms, which affect the accessibility of linguistic representations in the language processing system and result in a tendency to repeat previously encountered linguistic material (e.g., Pickering & Garrod, 2004). Alternatively, a more social account posits that accommodation in speech may be motivated by a desire to be liked by the conversational partner (Giles & Coupland, 1991). Later in this thesis, I will discuss a similar possibility, i.e. that linguistic imitation is directed by an unconscious goal to affiliate with the conversational partner.

3.4 Mimicry

When two people interact, they may imitate each other's behaviour. But interestingly, they do not always do it by choice – in some cases imitation is engaged unintentionally, and performed so discreetly it slips the conscious attention of both the imitating and the imitated person. For example, people tend to copy the mannerisms of the ones they interact with, and when they are talking with someone who occasionally rubs their face or shakes their foot, they tend to mimic this behaviour (Chartrand & Bargh, 1999). This phenomenon, known as mimicry, has been greatly explored in the last three decades of social psychological research. The list of mimicked behaviours has been found to be surprisingly long - people copy body posture (LaFrance, 1982; Tia, Saimpont, Paizis, Mourey, & Fadiga, 2011), handshake angle and speed (Bailenson & Yee, 2007), various mannerisms (Karremans & Verwijmeren, 2008; Lakin & Chartrand, 2003; Lakin, Chartrand, & Arkin, 2008; Stel et al., 2010; Yabar, Johnston, Miles, & Peace, 2006), and facial expressions of their interactional partners (Bavelas, Black, Lemery, & Mullett, 1986; Dimberg, Thunberg, & Elmehed, 2000). The ubiquity and power of this type of imitation inspired the investigations of its possible causal mechanisms (for reviews, see Chartrand & van Baaren, 2009; Chartrand & Lakin, 2013; Duffy & Chartrand, 2015; Kavanagh & Winkielman, 2016). It has been suggested that mimicry is socially adaptive, and that people imitate because it has positive consequences for their social interactions (e.g., Chartrand & Bargh, 1999). However, if mimicry is not a strategic act and it is engaged unconsciously, then how do people know it will benefit them? One prominent possibility is that people engage in mimicry as a result of an active unconscious goal to affiliate with others (Lakin et al., 2003). I will discuss the role of unconscious goals later in this review.

3.5 Automatic Imitation

In their laboratories, cognitive psychologists found an effect in many ways similar to mimicry. They discovered that people tend to imitate actions even when these actions are irrelevant or conflict with what they are doing at the moment, suggesting that this tendency is unintentional. For example, in one study participants were asked to open or close their hands in response to a colour cue superimposed on a video of an opening or closing hand (Stürmer, Aschersleben, & Prinz, 2000). Participants initiated their action faster in the presence of the video showing

the same action (e.g., participants opening hand when the video showed an opening hand), as compared to the video showing another action (e.g., participants opening hand when the video showed a closing hand). Importantly, the videos were irrelevant to the task and participants were not asked to pay any attention to them. Thus, faster action initiation in the presence of a video showing a matching action can be interpreted as evidence for an automatic tendency to imitate the observed actions. This finding, dubbed automatic imitation, have been replicated for a range of finger, hand, arm, foot, and mouth actions (e.g., Brass, Bekkering, Wohlschläger, & Prinz, 2000; Craighero, Fadiga, Rizzolatti, & Umiltà, 1998; for review, see Heyes, 2011). The tendency to imitate motor actions is commonly attributed to an automatic perception-action matching mechanism, i.e. an ability to instantaneously translate the perceptual representation of the observed action onto a motor plan for one's own action (Heyes, 2001, 2011). I will discuss this mechanism further in the subsequent sections of this review.

3.6 Imitative Learning

A very effective way to learn is to observe somebody demonstrate a novel action, and then imitate what they did. Different behaviours can be learnt this way, including languages (e.g., correct pronunciation), sports (e.g., skiing), playing musical instruments (e.g., learning to play staccato on piano), and many others. At least since Charles Darwin's (1871) work on evolution, imitative learning has intrigued researchers from different fields of psychology who ascribed it a crucial role in the acquisition and transmission of cultural knowledge (e.g., Hewlett et al., 2011; Shea, 2009; Vygotsky, 1978). And now, more than a century later, there is a great deal of evidence that both children and adults engage in imitation in order to learn (e.g., Bandura, 1962, 1977; Hewlett, Fouts, Boyette, & Hewlett, 2011; Morgan, Rendell, Ehn, Hoppitt, & Laland, 2012). Interestingly, the ability to learn through imitation appears extremely early in ontogeny and precedes language acquisition. Numerous studies showed that from the first year onwards, children imitate to learn new behaviours (for reviews, see Barr, 2010; Elsner, 2007; Nadel & Butterworth, 1999). For example, Shimpf, Akhtar and Moore (2013) found that toddlers readily copy a novel action performed on an object (e.g., pressing a button with an elbow to activate a sound) after it was demonstrated by a model. Moreover, they imitated even when the model was an unfamiliar stranger who did not interact with them.

Although it is debated how people acquire the ability to learn by imitating (e.g., Ray & Heyes, 2011), a widely held belief is that imitative learning (at least in its mature form) is an act of will, i.e. agents intentionally copy the observed action in an attempt to master it.

3.7 Overimitation

In their attempts to learn a new action, people often prove to be surprisingly indiscriminate imitators. When attempting to reproduce a novel behaviour, people do not only imitate, but overimitate: they sometimes copy all demonstrated actions, including ones that are unnecessary or incorrect (e.g., Flynn, 2008; Lyons, Damrosch, Lin, Macris, & Keil, 2011). For example, Horner and Whiten (2005) found that children who observed a model demonstrate how to open a novel box copied both the necessary (e.g., removing a bolt holding the door) and redundant actions (e.g., tapping on the surface of a box with a stick). The tendency to indiscriminately reproduce goal-relevant along with goal-irrelevant actions has been dubbed overimitation (Lyons, Young, & Keil, 2007). Importantly, much research in social and developmental psychology showed that such high-fidelity copying is not limited to young children, but is also found in older children and adults (McGuigan, Whiten, Flynn, & Horner, 2007; McGuigan, Makinson, & Whiten, 2010), who engage in overimitation even under time pressure (Flynn & Smith, 2012). Moreover, it appears that overimitation is not confined to the artifact domain, i.e. occurs also with behaviours that do that involve object manipulation. In a recent study, Subiaul, Winters, Krumpak, and Core (2016) showed that pre-school children imitated the model's incorrect pronunciation regardless whether the word was familiar or not, and even if they had previously correctly named the word. It is currently debated whether overimitation occurs across different communities and cultures (Nielsen, Mushin, Tomaselli, & Whiten, 2014; Nielsen & Tomaselli, 2010; for a discussion, see Berl & Hewlett, 2015). To distinguish overimitation from imitative learning, some researchers stress it involves copying the irrelevant actions despite knowing the actions that are conventional, necessary, or correct in a given context (Subiaul et al., 2016). So defined, overimitation might appear to be driven by some automatic mechanism that is outside intentional control. Although several such mechanisms have been proposed, recent evidence points towards a possibility that

overimitation might be in fact a rational, and intentional act (Keupp, Behne, Zachow, Kasbohm, & Rakoczy, 2015; Keupp, Bancken, Schillmöller, Rakoczy, & Behne, 2016).

4 WHERE DO IMITATIVE BEHAVIOURS COME FROM?

The ubiquity of imitative behaviour resonated in a vigorous debate about the origins of imitation. And as psychology has seen many times before, it is a debate between nature and nurture (or at least it closely resembles the nature vs nurture debate; for reviews, see Cook, Bird, Catmur, Press, & Heyes, 2014; Decety & Meltzoff, 2011; Heyes, 2010).

One view in this discussion assumes that imitative behaviours result from an innate, genetically encoded ability to match an observed action with a representation of this action in one's mind (e.g., Meltzoff & Moore, 1997). According to a strong version of this view, motor and sensory experience gained throughout the development plays a minor role in this ability (see Cook et al., 2014). On a neural level, this ability is warranted by a discovery of specialised neural cells, dubbed mirror neurons. These neurons fire both when the action is performed by an agent and when the agent observes it being performed by another (e.g., di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Iacoboni, Woods, Brass, Bekkering, Mazziotta, & Rizzolatti, 1999; Mukamel, Ekstrom, Kaplan, Iacoboni, & Fried, 2010; for reviews, see Kilner & Lemon, 2013; Ferrari & Rizzolatti, 2014; Rizzolatti & Craighero, 2004). The proponents of the innate view argue that mirror neurons are present already at birth, and that this shows they are genetically encoded (e.g., Casile, Caggiano, & Ferrari, 2011; Gallese, Rochat, Cossu, & Sinigaglia, 2009).

However, the other side of the debate claims that the ability to elicit imitative behaviours (and the neural basis for this ability, i.e. mirror neurons) is acquired at the postnatal stages of the development (e.g., Catmur, Walsh, & Heyes, 2009). In this view, the ability to imitate is a product of associative learning that creates connections between sensory and motor neurons. As a result of this learning, brain areas responsible for observing and executing actions are linked into one network of mirror neurons (Cook et al., 2014; Heyes & Ray, 2000). Both the nativist and the associative account rely heavily on evidence from developmental studies. Below, I briefly review findings on imitative behaviours throughout ontogeny.

4.1 Imitative Behaviours across Development

Most of the evidence suggests that people engage in imitative behaviours from the very first hours of their lives. For example, new-born babies cry when they hear other babies cry (for a review, see Geangu, Benga, Stahl, & Striano, 2010). In the first study to test this effect using a controlled experimental paradigm, Simner (1971) found that the number of infants who engaged in crying was greater in the group that heard a recording of another baby's cry, as compared to the group that heard a recording of white noise of similar intensity, or the group that was not exposed to any sounds. Moreover, there exists a large body of evidence suggesting that new-born infants also show a tendency to copy other types of behaviour, including tongue protrusion, head movements and facial expressions (e.g., Jacobson, 1979; Meltzoff & Moore, 1983; Meltzoff, 2002; Termine & Izard, 1988). However, these findings are currently under scrutiny due to concerns that they do not in fact demonstrate imitation (Jones, 1996, 2006) and that the evidence for some of the imitative behaviours is indecisive (for reviews, see Anisfeld, 1996; Ray & Heyes, 2011). Crucially, there is a consensus that the tendency to imitate is observable at early developmental stages, whether it is the first hours or months after birth. Furthermore, the repertoire of imitative behaviours expands throughout childhood (for reviews, see Jones, 2007, 2009; Meltzoff & Williamson, 2013) and persists in adulthood (for reviews, see Chartrand & Lakin, 2013; Heyes, 2001, 2011).

5 IMITATIVE BEHAVIOURS: INSTANCES OF THE SAME OR DIFFERENT PHENOMENA?

As shown in the previous sections, social coordination can manifest itself in many behaviours that involve copying other people. Agents might engage in synchrony, emotional contagion, imitative learning, linguistic imitation, overimitation, mimicry, and automatic imitation. Importantly, these behaviours differ from each other in some aspects, but bear a resemblance to each other in others. This creates a tension between an intuition that they might be instances of the same phenomenon, and the observation of apparent differences that could suggest that imitative behaviours may be caused by multiple mechanisms. In an attempt to illustrate this tension, I now turn to discuss some of the similarities and differences between these behaviours.

5.1 Similarities and Differences between Imitative Behaviours

All of the imitative behaviours reviewed in the previous sections occur in a presence of another agent and involve copying of some features of the behaviour exhibited by this agent. However, they might differ in other aspects and several distinctions can be made to reflect these differences.

First, the imitative behaviours reviewed here differ with regards to the features of the other agent's behaviour that are being imitated. For instance, in synchrony agents copy the entire temporal structure of behaviour, but it is not essential for them to copy its other features (e.g., type of action involved). Conversely, imitative behaviours other than synchrony occur with a delay, i.e., agents engage in imitation after the onset of the action performed by the other agent. Thus, they might involve copying some (e.g., sequential order of actions constituting the behaviour, action duration), but not all temporal features. Instead, agents focus on imitating other features (e.g., spatial trajectory, velocity).

Second, imitative behaviours might be associated with different modalities. More specifically, linguistic imitation is concerned with copying various (sometimes abstract) aspects of language (e.g., lexical, syntactic, prosodic), emotional contagion with copying emotional states and their physiological correlates (e.g., facial expression, visceral correlates of emotion, mental states), whereas the remaining imitative behaviours primarily involve copying motor movements.

Third, some imitative behaviours appear to require conscious intention, whereas others seem to be performed unintentionally. In other words, some can be linked to planned coordination (imitative learning), whereas others arise from the mechanisms of emergent coordination (emotional contagion, mimicry, automatic imitation). However, note that some imitative behaviours can be either planned or emergent (synchrony, linguistic imitation).

Finally, an imitative behaviour might involve actions that are novel or familiar to the agent. This distinction allows us to differ between behaviours that involve learning (imitative learning, overimitation) and those that typically do not (synchrony, emotional contagion, linguistic imitation, mimicry, automatic imitation).

5.2 Modern Classifications of Imitative Behaviours

In modern psychology, several classifications have been proposed to capture and meaningfully describe the diversity of imitative behaviours. Notably, some researchers distinguished between instances when agents imitate in order to learn a new behaviour and those when they imitate for other purposes. For example, Uzgiris (1981) proposed discerning between imitation to learn and imitation to be social (see also Byrne & Russon, 1998).

Others included the distinction between imitative learning and other types of imitation, while attempting to also accommodate for the fact that people can imitate different types of behaviour. In his classic model, Piaget (1929, 1951) distinguished between simple imitation, that involved copying single, familiar actions, and complex imitation, that involved copying multiple or novel actions. Moreover, he also suggested that it is important whether the agent can observe themselves producing the imitative behaviour (e.g., copying an action involving an object), or not (e.g., copying a facial expression). More recently, Subiaul (2010) proposed a similar classification that makes a distinction between the behaviours that involve copying of familiar versus novel actions, and between the vocal, motor, and cognitive modality of the imitated behaviour.

Another distinction is that of intentionality, and it has been particularly important for the accounts that focus on the social character of imitation. Researchers investigating the phenomenon of social mimicry assume it to be always unconscious, i.e. to occur without the conscious awareness of either of the agents involved (e.g., Chartrand & Bargh, 1999). These accounts contrast unconscious and conscious imitation, and may also include an additional distinction between the different behaviours that are imitated, e.g., facial, emotional, verbal, and behavioural (Chartrand & van Baaren, 2009).

Lastly, the timing of occurrence of the imitative behaviour has also been considered by some classifications. For example, Bandura (1969) distinguished between imitation that occurs simultaneously with the imitated behaviour (or immediately thereafter) and imitation that occurs with a delay. Importantly, the proponents of this distinction have argued that immediate and delayed imitative responses are qualitatively different phenomena (see Zentall, 2006).

5.3 Single- versus Multiple-Mechanism Theories of Imitation

In response to the diversity of imitative behaviours, two general types of theories have been proposed. The first type posits that different imitative behaviours are manifestations of the same phenomenon, and that a single mechanism or a single system of mechanisms is responsible for imitation. The second type refers to imitation in a generic sense and proposes that it is an umbrella term for multiple distinct phenomena. Consequently, these theories argue that there are multiple mechanisms capable of eliciting imitative behaviours.

Single-mechanism theories have been considered in psychology since Romanes, who suggested that simple forms of imitation are homologous antecedents of complex imitation (Galef, 2013). Many other researchers adopted this view ever since (e.g., Buller, 2006; Byrne, 2005; Iacobini, 2005). Perhaps the most prominent modern single-mechanism theory is the Associative Sequence Learning account (ASL) (Catmur et al., 2009; Cook et al., 2014; Heyes, 2001, 2005, 2011). The ASL proposes that imitation relies on the ability to translate the observed action onto a motor plan that can then be used to produce the same action. For instance, to imitate an adult who is waving good-bye, a child needs to translate the perceptual representation of the action performed by the adult onto a motor representation that the child would typically engage to perform the same action. This translation is achieved by an automatic perception-action matching mechanism, which on a neural level is warranted by a bidirectional activation link between the sensory and motor areas in the brain (i.e., mirror neurons). The perception-action matching mechanism develops through associative learning and once it is in place, it leads to an automatic activation of the action plan whenever this action is observed. Importantly, it has been suggested that this mechanism is responsible for generating both simple (i.e., automatic imitation and mimicry) and complex types of imitation (i.e., imitative learning) (Catmur et al., 2009; Heyes, 2001, 2011).¹

¹ However, these authors are cautious in their suggestion that behaviours other than automatic imitation might be caused by perception-action matching.

The multiple-mechanism approach dates back to Morgan (1900), who distinguished between imitation produced by an instinct, or resulting from a conscious reflection. He noted that superficially identical behaviours may in fact be caused by these two distinct mechanisms. This core idea has been echoed in the work of other prominent thinkers (e.g., Piaget, 1951; Nadel, 2006; Meltzoff & Moore, 1997; Subiaul, 2010; Subiaul, Anderson, Brandt, & Elkins, 2012). For example, Piaget (1951) proposed that imitation requires a whole set of cognitive skills, which are acquired at different developmental stages. The development of a skill precedes the ability to engage in an imitative behaviour that relies on it. Similarly, Jones (2007, 2009) reviewed the existing developmental evidence and argued that different types of imitation appear at different ages, indicating there is no single imitative mechanism or system underlying all of them. Instead, she proposed a multi-component model in which imitation is a product of the coming together of motor and cognitive skills, and social knowledge and motivation. For example, to the child who wants to imitate an adult waving good-bye needs to have developed the cognitive and motor skills required for observing and identifying the action, be able to perform the action, and know the social norms that dictate who (and when) can be imitated (e.g., imitating a family member is accepted, but imitating strangers might not be).

6 THE TYPE OF IMITATION CONSIDERED IN THIS THESIS

As I demonstrated in the previous sections of this review, imitation continues to be investigated under different theoretical banners, with different methodologies, and sometimes using conflicting terminology (see Heyes, 1996). Given these conflicting approaches, it is important to clarify how the term imitation will be used in this thesis.

6.1 A Broad Definition of Imitation

In this thesis, I adopt a broad definition of imitation. Although the term imitation has been sometimes used to refer to an ability or faculty (e.g., Meltzoff & Moore, 1997; Subiaul, 2010), I propose to use it as a description of a behavioural phenomenon. Here, I define imitation as *a non-random act of copying some or all aspects of a behaviour observed in another agent*. According to this definition, an action can be considered imitative if it shares some or all

features with a behaviour that was earlier produced by another agent. Moreover, it must occur with an above-chance probability and as a result of observing another agent (cf. Morgan, 1900).

Note, that this definition does not include imitation of mental phenomena, i.e., psychological emotional states (e.g., Moody, McIntosh, Mann, & Weisser, 2007), abstract rules (e.g., Subiaul et al., 2007), and goals (e.g., Carpenter & Call, 2002). Crucially, I do not wish to claim that agents do not adopt these mental constructs. For example, there is considerable evidence that agents engaged in imitation and other types of social coordination may at times pursue a shared goal (e.g., Carpenter, Call, & Tomasello, 2005; Gergely, Bekkering, & Király, 2002). However, as I will argue later, adopting a common mental construct could be one of the mechanisms responsible for imitation, and not an imitative behaviour itself.

There are several advantages of adopting this definition. First, a behavioural definition capitalises on the strong evidence supporting imitation of observable behaviour in animals and humans, and aids experimenters in their attempts to operationalise imitation. Second, so defined imitation is a broad class of behaviours that contains all of the different types of imitative behaviour currently discussed in the literature.² Third, this definition is theoretically neutral and as such welcomes the investigations of competing accounts of imitation.

This creates a space both for researchers who wish to test the hypothesis that imitation results from a single domain-general mechanism (e.g., Buller, 2006; Catmur et al., 2009), and for those who suggest that different types of imitative behaviour arise from multiple different domain-specific mechanisms (e.g., Subiaul, 2010). A broad definition could also encourage investigations that test the scope of the existing accounts of imitation by applying them to different imitative behaviours. For example, in social psychology imitation has been explained by the pursuit of unconscious social goals (Lakin, Jefferis, Cheng, & Chartrand, 2003). However, the evidence for it relies heavily on research in one domain, i.e. unconscious

² But note that in case of emotional contagion only the behavioural component (e.g., facial expression, posture) can be accounted for under this definition.

behavioural mimicry. To prove that social goals might cause also other types of imitation, one would need to test the predictions derived from this account with regard to other imitative behaviours, e.g. language. Such cross-examination of the existing accounts could greatly benefit the research on imitation.

6.2 Planned versus Emergent Imitation

There is one more distinction that I would like to mention here. For more than a century, researchers have distinguished between the instances of imitation that seem automatic and those that appear to involve deliberation (e.g., Morgan, 1900; for reviews, see Bavelas et al., 1987; Galef, 2013). Recently, Hale and Hamilton (2016) divided social coordination into behaviours that involve engaging in the same versus different action than the other agent, and into those that occur simultaneously with the action of the other agent versus after a delay. Moreover, consistently with the century-old tradition, they distinguished between behaviours that are “deliberate and goal-directed” and “unconscious and spontaneous”. Behaviours that occur after a delay and involve engaging in the same action are termed imitation, if they are goal-directed, or mimicry if they are spontaneous. However, for the needs of this thesis I propose an alternative to the authors’ distinction between imitation and mimicry. Instead, I distinguish between imitative behaviours that result from the mechanisms of planned versus emergent coordination (henceforth: *planned* vs. *emergent imitation*).

Agents engage in planned imitation as a result of a shared goal which specifies the imitative behaviour as a part of a joint action. Importantly, I assume that this shared goal is pursued intentionally. For example, the string section in an orchestra might play in unison, because the musicians in this group share a goal to jointly perform a musical piece. Note that in this case, the goal is not specifically about imitating others, but it elicits the imitative behaviour as a part of a more complex sequence of behaviours involved in the joint action. On other occasions, however, the shared goal might specifically require one or more agents to imitate. Imitative learning could serve as an example here. When an agent imitates to learn, the goal is to take a role of an observer who watches the other agent demonstrate an action, and then attempts to reproduce it.

Conversely, emergent imitation arises spontaneously, due to the automatic mechanisms of coordination. For example, a speaker in a conversation might imitate the speech rate of the other speaker. Apart from the rare cases when such adaptation could arguably serve the goal to communicate (e.g., speaking at a noisy dinner table), emergent imitation is not motivated by an intentional pursuit of a shared goal. Instead, it is caused by some of the automatic mechanisms that govern social coordination (e.g., temporal adaptation). As I demonstrated in the previous sections of this review, it remains somewhat unclear which imitative behaviours occur spontaneously and thus could be categorised as emergent. However, drawing on the current literature, I propose that emergent imitation includes mimicry, emotional contagion, automatic imitation, and at least some forms of imitation in language.

Importantly, the distinction between emergent and planned imitation is different from the conscious-unconscious distinction prominently featured in the mimicry literature (see Chartrand & Lakin, 2013). According to the latter, a behaviour is either considered to be consciously engaged and executed or entirely unconscious. Moreover, a strong version of this distinction suggests that unconscious behaviour remains unnoticed by both of the interacting agents (Chartrand & van Baaren, 2009). However, it is plausible to assume that the imitative behaviour might be noticed by either of the conscious agents at some point of its duration. For example, a speaker interacting with a partner who is imitating their speech rate might spot this emergent similarity, especially if the scale of adaptation is big (e.g., changing from very fast to very slow). The same could be true for the imitator who might initiate the behaviour unconsciously, but become conscious of it at some later stage. Furthermore, the conscious-unconscious distinction proposed in the mimicry literature confounds conscious awareness with automaticity, and assumes that only the behaviours that are unconscious are automatic (e.g., Chartrand & Bargh, 1999). Unfortunately, this led many researchers interested in the automatic mechanisms of imitation to limit their investigations to behavioural mimicry, while largely ignoring other imitative behaviours (e.g., automatic imitation).

I argue that the emergent-planned distinction could ultimately help to discern the imitative behaviours that result from the automatic mechanisms and those driven by an intentional goal pursuit. This is because it does not make any assumptions about conscious awareness and therefore avoids the problems that are related to it. Furthermore, it is consistent with the vast

body of literature on social coordination, rather than being inspired by a particular approach in imitation research (which could be potentially limiting).

6.3 Investigating Emergent Imitation in Motor Action and Language

In the following parts of this thesis, I will focus on emergent imitation – imitation that is brought about as a result of automatic, involuntary mechanisms, rather than the intentional pursuit of a shared goal. Moreover, I assume that emergent imitation is brought about by multiple causal mechanisms, i.e. an agent may engage in different imitative behaviours as a result of distinct mechanisms. However, I do not make any assumptions about the correspondence between these mechanisms and imitative behaviours. Although in most cases different behaviours result from distinct mechanisms (e.g., imitation of rhythm results from temporal adaptation, and automatic imitation of motor action results from perception-action matching), it is possible that sometimes different behaviours might result from the same mechanism (e.g., behavioural mimicry and linguistic imitation might both result from an active goal to affiliate). Furthermore, from my definition of imitation it follows that I consider only imitation of directly observable behaviours, and not mental constructs. Specifically, in this thesis I focus on imitation of familiar behaviours (as opposed to novel), and in the following sections I discuss the mechanisms that lead to emergent imitation in motor action and language.

6.4 Automatic Mechanisms of Emergent Imitation

Agents may engage in emergent imitation due to the automatic mechanisms that contribute to social coordination. In the following sections, I discuss three such mechanisms: simulation, temporal adaptation, and the unconscious goal to affiliate. Consistent with the multiple-mechanism approach, I assume that all three might play a causal role. As I will demonstrate, each of these mechanisms could potentially explain one or more of the existing imitative behaviours. In the next section, I start by reviewing the evidence for the simulation mechanism and discussing its relationship with imitation.

7 SIMULATION

The recent discovery of mirror neurons and further advances made by studies employing neurophysiological methods confirmed the existence of a direct link between perception and action. Perceiving a movement performed by someone else automatically elicits an activation in the observer's motor system. But what is the purpose of this activation? An important movement in cognitive sciences argues that agents use their own motor system to simulate the actions they observe. This way, they can predict what will happen next.

Importantly, the engagement of the motor system during action simulation has been linked to imitation. More specifically, it has been proposed that agents simulate by covertly imitating the observed action. In the following section, I suggest that this covert imitation subserves the ability to overtly imitate by pre-activating the specific parts of motor system that are needed to imitate the observed action. I further argue that the simulation mechanism is also active in language processing, and therefore covert imitation of the comprehended utterances could explain some instances of linguistic imitation.

7.1 Evidence for Perception-Action Matching

A large number of studies demonstrates that observing an action elicits a corresponding motor representation in the brain. More specifically, perception of body movements is associated with an increased activation in the areas responsible for motor planning and execution. This effect, known as perception-action matching, is believed to be achieved by a network of brain areas involving mirror neurons (e.g., Cook et al., 2014; Heyes, 2011). There is rich neurophysiological evidence confirming that perception-action matching commonly occurs during action observation. Function magnetic resonance imaging (fMRI) studies found that the cortical areas related to motor action are activated when observing foot, finger, hand, arm, or mouth movements (e.g., Aziz-Zadeh, Koski, Zaidel, Mazziotta, & Iacoboni, 2006; Buccino et al., 2001, 2004; Grezes, Armony, Rowe, & Passingham, 2003; Iacobini et al., 1999; Lahav, Saltzman, & Schlaug, 2007; Rizzolatti et al., 1996; Stevens, Fonlupt, Shiffrar, & Decety, 2000). Similarly, the sensorimotor mu rhythm in the electroencephalogram (EEG), which is normally present during the resting state of the brain, has been shown to disappear both when an action is observed and when it is executed (e.g., Marshal & Meltzoff, 2014; for reviews,

see Rizzolatti, Craighero, & Fadiga, 2002; Perry & Bentin, 2009; Pineda, 2005). Furthermore, motor evoked potentials (MEP) studies showed that hand muscles are facilitated in response to watching an action performed by a hand (e.g., Catmur, Mars, Rushworth, & Heyes, 2011; Clark, Tremblay, & Ste-Marie, 2003; Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995). For example, observing index and thumb movements selectively facilitates the potentiality of the specific finger muscles involved in producing the same movement (Maeda, Kleiner-Fisman, & Pascual-Leone, 2002).

7.2 Simulating Others through Covert Imitation

These dramatic findings have reignited the interest in a long-standing hypothesis that observers use their minds and bodies to simulate the actions they perceive (e.g., Carpenter, 1874/1984; James 1890; Smith, 1759/1976). Drawing on the evidence for the involvement of the motor system during action observation, several modern accounts proposed that agents simulate the observed actions through an automatic and covert process similar to overt motor imitation (e.g., Fadiga, Craighero, & Olivier, 2005; Jeannerod, 2001; Kilner, Friston, & Frith, 2007; Springer, Parkinson, & Prinz, 2012; for reviews, see Decety & Grèzes, 2006; Prinz, 2006). Importantly, many of these accounts incorporate perception-action matching into the simulation mechanism.

For example, Wilson and Knoblich (2005) suggested that action simulation engages the parts of the motor system that would normally be used to produce this action. Crucially, the purpose of this covert motor imitation is to generate predictions about the future states of the perceptual system. Observers can then use these predictions to fill in for missing or ambiguous sensory information, and to ready themselves for the upcoming perceptual input. An ability to predict perceptual input could greatly benefit the agent, e.g., allow to bypass the delay of sensory transmission, support the interpretation of ambiguous input, and help to prepare a response.

But how exactly are these perceptual predictions generated? One possibility is that the perceptual system employs an internal forward model (Wilson & Knoblich, 2005; cf. Gazzola & Keysers, 2009; Wolpert, Doya, & Kawato, 2003). In this view, the perceptual representation of the observed action is translated into a motor command that would normally lead to executing an identical action. Note that this stage utilises the perception-action matching

mechanism. The motor command is subsequently fed into the forward model, which engages the motor system to simulate the unfolding of the action. The forward generates the predicted states of the motor system using the principles and regularities of a given action that are internalised by the system (e.g., typical trajectory, typical sequence of movements). The simulated states of the motor system are then translated into perceptual representations equivalent to those that would be produced if the action was perceived. Such simulation mechanism is a form of covert motor imitation. Just like overt imitation, it requires an activation of the motor plan for the action. Moreover, it involves a sub-threshold engagement of the motor system which closely resembles the engagement that would result from overtly imitating the action (cf. Fadiga et al., 2005).

To give an example of an application of the simulation mechanism, let's consider an interaction where one agent (the observer) sees another (the actor) extending her right hand towards a coffee mug. To predict what is the actor about to do, the observer engages in simulation. First, the visual representation of the action in the observer's mind is translated (using the perception-action link) into a command for extending the right hand. This command is then fed into the forward model which engages the brain motor areas and muscles normally responsible for performing this movement with the observer's right hand. The model generates a series of predicted states of the motor system, e.g., extending the hand, moving it closer to the mug, and grasping the mug. Each of these states produces proprioceptive feedback from the muscles involved, which is matched with a motor command that is typically associated with this feedback. The commands generated at this stage allow the observer to predict the unfolding of the action, and can be translated into visual representations to prepare the visual system for the upcoming input. Thus, the simulation of the actor's action involved engaging the same motor areas and muscles, and in the same order, as would be engaged if the observer would overtly imitate the action.

7.3 Evidence for Action Simulation

There are several sources of evidence supporting the claim that agents use their motor system to simulate the actions of others beyond the immediate perception-action matching mechanism (Wilson & Knoblich, 2005). First, the motor simulation account suggests that the activation of

motor areas occurring during action perception is due to predictive processing. In support of this, it has been found that areas responsible for planning are active during action observation (Caspers, Zilles, Laird, & Eickhoff, 2010). Moreover, motor control areas specific to the observed action are active before the predicted action (Haueisen & Knösche, 2001). Second, motor simulation requires the observers to engage their own motor system as they would if they were overtly imitating the action. Thus, action familiarity should modulate the motor system activation. In agreement with this prediction, areas responsible for planning are activated more strongly when the observed (or expected) action is within the observer's repertoire (Aglioti, Cesari, Romani, & Urgesi, 2008; Calvo-Merino, Grèzes, Glaser, Passingham, & Haggard, 2006; Lahav et al., 2007; cf. Vogt et al., 2007). Action imitability is another factor that should modulate the neural response, i.e. the motor system should be unable to simulate an action that is difficult or impossible to imitate. Indeed, it has been shown that inimitable actions (e.g., impossible rotation of an arm) do not elicit the typical representational response (Stevens et al., 2000), and there is some (although mixed) evidence that the motor activation effects are attenuated or absent when observing an action performed by a non-human agent (see Hofree, Urgen, Winkielman, & Saygin, 2015; Liepelt, Prinz, & Brass, 2010).

7.4 How Can Simulation Lead to Imitation?

Overall, recent findings support the claim that agents simulate the actions of others. Critically, the motor simulation mechanism involves an activation of the motor system that closely resembles the activation otherwise elicited by overt imitation of actions (Wilson & Knoblich, 2005). This similarity led some researchers to suggest that covert motor imitation might serve as basis for overt imitative behaviours (e.g., Iacobini et al., 1999; Rizzolatti, Fogassi, & Gallese, 2001). There has been a debate whether simulation and imitation share a neural network, with mirror neurons being the main candidate for such network (see Heyes, 2001; Brass & Heyes, 2005; Turella, Erb, Grodd, & Castiello, 2009). Recently, several meta-analyses of neurophysiological studies confirmed that mirror neurons are involved in imitation (Molenberghs, Cunnington, & Mattingley, 2009, 2012), and that the motor areas that are active during action observation are also active during overt imitation (Caspers et al., 2010). This suggests that simulation and imitation may rely on a common neural network that encompasses

parts of the motor system. On the level of mental representations, it is likely that the simulation mechanism might activate the same motor plan that is used in overt imitation. As a result of the neural and representational overlap between simulation and imitation, watching another person engage in a particular behaviour might prime this behaviour in the observer, therefore increasing the chance of imitating it (cf. Chartrand & Bargh, 1999; Dijksterhuis & Bargh, 2001; Byrne & Russon, 1998). This way, the automatic and largely unconscious motor simulation (Decety & Grèzes, 2006) could encourage the interacting agents to spontaneously imitate each other.

7.5 Why Don't People Imitate All the Time?

However, a theoretical conundrum arises here: if simulation involves the motor plan that is also used to produce overt imitative behaviour, then agents should automatically imitate whenever they observe the other perform an action. Yet, they obviously do not do that. In fact, social coordination sometimes requires complementary, rather than imitative actions (e.g., Sartori, Cavallo, Bucchioni, & Castiello, 2012; Sebanz et al., 2006).

Experimental studies confirmed that the activation of the motor plan is malleable (for a review, see Bardi, Bundt, Notebaert, & Brass, 2015). For example, Catmur, Walsh, and Heyes (2007) demonstrated that the imitative activation during action observation can be reversed. They trained participants to make an index finger movement while observing a little finger movement, and vice versa. After training, the MEPs measurement indicated an activation pattern that was opposite to what is typically observed: the activation in the little finger muscle was greater when observing the index finger movements than the little finger movements. Further studies found that imitative activation can be suppressed in the context of complementary actions (e.g., Newman-Norlund, van Schie, van Zuijlen, & Bekkering, 2007; Barchiesi & Cattaneo, 2013; Sartori, Betti, & Castiello, 2013) or simply by instruction to perform a non-imitative action (Bardi et al., 2015).

Together, these findings suggest that motor simulation must be complemented by an inhibition mechanism, which contains the activation of the motor system at a sub-threshold level, thus preventing overt imitation (cf. Fadiga et al., 2005; Jeannerod, 2001). A system comprising simulation and inhibition mechanisms would grant the agent the ability to generate predictions

about the upcoming external events, while allowing selective, rather than indiscriminate imitation of the observed actions. The existence of an inhibition mechanism has been convincingly demonstrated at the behavioural level using the Stroop task and go/no-go paradigms (for reviews, see Logan & Cowan, 1984; MacLeod, 1991). However, on the neural level, the hunt continues. For example, clinical studies show that patients with frontal lobe damage may exhibit an uncontrollable tendency to imitate, suggesting this area is responsible for inhibiting overt imitation (e.g., De Renzi, Cavalleri, & Facchini, 1996; Lhermitte, Pillon, & Serdaru, 1986). Other studies point towards the structures in the spinal cord (e.g., Baldissera, Cavallari, Craighero, & Fadiga, 2001), frontal lobe (Brass, Derrfuss, & von Cramon, 2005) and prefrontal cortex (Brass, Zysset, & von Cramon, 2001; for a review, see Brass, Ruby, & Spengler, 2009).

Recent accounts posit that the brain system for imitation includes both the perception-action link used for simulation and the areas responsible for imitation inhibition. For example, Wang and Hamilton's (2012) social top-down response modulation (STORM) model proposes that covert activation of the motor system provides agents with a basic tendency to imitate the observed actions. However, a control mechanism is also in place to ensure that agents do not unnecessarily engage in overt imitation. The control mechanism reacts selectively to certain environmental cues (e.g., social context, evaluation of the interaction partner) and at times allows the agents to engage in imitative behaviour.

In sum, covert activation of the motor system plays an important role both in motor simulation and overt motor imitation. Importantly, it is unlikely to be dedicated to imitation alone (Hamilton, 2015). Rather, it serves the mechanism of motor simulation (e.g., Wilson & Knoblich, 2005) and may subserve imitation (Prinz, 2006) by pre-activating the parts of the motor system that are needed to engage in imitative behaviour.

8 SIMULATING OTHERS IN LANGUAGE

As it can be seen in the previous sections of this review, most of the evidence for the simulation mechanism comes from research into the motor domain, and the mechanism itself is believed to rely on the covert activation of the brain areas normally involved in executing motor movements. So should we conclude that simulation is limited to this domain only? Not

necessarily. According to some recent accounts in psychology of language, people engage the simulation mechanism also when they perceive language (e.g., Dell & Chang, 2014; Pickering & Garrod, 2007, 2013; cf. Hickok, 2012). With regard to dialogue, Pickering and Garrod (2013) proposed that listeners covertly use aspects of their language production system in order to predict what the speaker is about to say.³

According to this account, a listener first uses his comprehension implementer to form a percept of the speaker's utterance at a given time. This percept is an abstract linguistic representation comprising semantic, syntactic and phonological information about the utterance, and it is formed in response to the perceptual input (e.g., auditory signal). Next, the listener translates the percept into a production command that he would send to produce this utterance if he was speaking himself. This is done by a special type of a mental computational process, called an inverse model, which engages aspects of the language production system to covertly imitate the perceived utterance. Using prior experience of language production, the inverse model determines the production command that typically results in the given percept. Moreover, the model also needs to accommodate for the fact that it is the listener's production command that has to be derived from the percept of the speaker's utterance. To achieve this, the model uses the available information about the context in which the utterance occurs (e.g., information about the differences in pronunciation between the listener and the speaker).

Once the production command for the perceived utterance has been determined, it is fed into a forward model. The forward model is a computational process that engages the listener's production system to predict the utterance that the speaker is most likely to say next. However, only some aspects of the production system are engaged, and consequently the output from the model is typically an impoverished representation of the predicted utterance (comprising

³ Pickering and Garrod (2013) proposed that simulation is crucial both for comprehension and production of language, and that it is likely to be used whenever processing language. However, in this thesis I focus on the case of comprehending language while engaged in dialogue, because of its potential relevance for linguistic imitation.

some elements of semantic, syntactic and phonological information). Finally, this representation is translated into a predicted percept of the upcoming utterance by a forward comprehension model. This percept represents the perceptual features of the predicted utterance, and can be used to help the listener in several ways.

Specifically, when the speaker will actually produce the predicted utterance, the listener will be able to use the predicted percept to aid the comprehension of this utterance. Moreover, the listener will be able to compare the predicted percept with the actual percept of the utterance (again formed using the comprehension implementer) and assess the accuracy of his prediction. In case of a discrepancy between the prediction and the utterance, corrections will be implemented into the forward model so that it is capable of generating more accurate predictions in the future. This is a very important step, because it allows the listener to adapt his forward model to the particular speaker.

Crucially, Pickering and Garrod assume a parity between language comprehension and production: they propose that the same forward model is used to simulate the utterances of the other people during comprehension and to simulate one's own utterances during production. Thus, any corrections made to the forward model while comprehending the speaker will prevail in the model when it will be used to produce an utterance later in the conversation.

To illustrate the use of the simulation mechanism in comprehension, let's consider a situation where a listener hears the speaker say: *The tray is really hot, so don't grab it without a mitten*. As the sentence unfolds, the listener continuously uses the simulation mechanism to generate predictions about the word that he is most likely to hear next. For the sake of brevity, let's focus on a single iteration of the simulation mechanism, i.e. at the time when the speaker have produced the sentence up to the penultimate word. At this point, the listener first forms a percept of the speaker's utterance thus far (*The tray is really hot, so don't grab it without a*). He then translates the percept into a production command he would use to produce this utterance, and derives a further command for a word he would typically say next (*mitten*). Subsequently, the command for the next word is used to generate a linguistic representation of the predicted utterance, which is then translated into a percept of the predicted utterance. At this stage, the listener can use this prediction to prepare his perceptual system for the upcoming input, utter the predicted word, estimate the end of the speaker's turn to plan his response, or

engage in another type of action ahead of the end of the speaker's turn (e.g., start looking for a mitten).

8.1 Can Language Simulation Contribute to Linguistic Imitation?

I propose there are at least three reasons why the mechanism described by Pickering and Garrod could result in a tendency to imitate various aspects of one's conversational partner.

First, engaging aspects of the production system to simulate the partner's utterance during comprehension is likely to facilitate overt production of this utterance. The logic of this argument is similar to the one in case of motor simulation: the inverse model automatically translates the perceived utterance into a production command which becomes pre-activated in the comprehender's language system. This makes it easier to overtly produce the perceived utterance, as opposed to some other utterance that was not perceived and therefore did not receive such pre-activation.⁴

Second, a given utterance should receive activation both from a production command derived by a current inverse model and from the prediction generated by a previous forward model. Given that simulation is likely to be used continuously during comprehension, an utterance that occurs at a given point in time previously was a target for the forward model which already generated a prediction for it. This prediction should have increased the availability of the utterance in the comprehender's language system even before it can be actually perceived.

⁴ Note that this argument faces a similar problem as its motor counterpart, i.e. it has to address the question of why people do not always imitate the language of their conversational partners. Pickering and Garrod do not provide an explicit answer to this question, and their account does not include an inhibitory mechanism. However, they suggest that a production act is initiated by intention. It is therefore possible that although the simulation mechanism facilitates imitation of the perceived utterance, intention is necessary to evoke overt imitative production.

Thus, previous (correct) predictions could provide a second source of activation for the utterances produced by one's conversational partner.⁵

Third, the ability to train the forward model to correct for the prediction error should result in a tendency to adapt to the conversational partner. Since comprehension and production both utilise the forward model, any changes made to it in comprehension will prevail in production, which in turn will affect one's subsequent production acts. For example, listening to a speaker who has a strong accent should leave a mark on one's subsequent production, such that one's own pronunciation should resemble certain phonetic characteristics of this accent. Other aspects of language like prosody or speech rate could also be imitated as a result of adapting one's forward model to the partner (see Gambi & Pickering, 2013).

For the reasons outlined above, language simulation mechanism might promote automatic imitation of various aspects of language between the conversational partners. Interestingly, linguistic imitation might in fact be something more than a by-product of simulation. Pickering and Garrod suggest that imitation might play an important role in dialogue: imitating makes one more similar to the conversational partner, which is a way of making oneself more predictable. For instance, adapting to the partner's accent should increase the chances that his inverse model will derive correct production commands and that his forward model will generate accurate predictions of one's speech. Thus, imitation between conversational partners should aid comprehension, and lead to smooth and efficient dialogue.

⁵ This suggests that utterances that elicited strong predictions during comprehension should be more likely to be subsequently produced by the listener. To my knowledge, this possibility has not yet been tested.

8.2 Evidence for Language Simulation

Engaging the production system to simulate others is likely to result in a tendency to overtly imitate various aspects of the language used by one's conversational partner. Here, I briefly review the evidence for the involvement of simulation in language.

Given that the primary function of simulation is to allow prediction, findings demonstrating that people engage in linguistic prediction would provide some support for the involvement of simulation in language. Indeed, a large body of research shows that when reading or hearing language speakers generate expectations about what they will see or hear next (for reviews see, Dikker & Pylkkänen, 2013; Federmeier, 2007; Kutas & Federmeier, 2011; Pickering & Garrod, 2007). Numerous studies have demonstrated that people are able to predict phonological (e.g., DeLong, Urbach, & Kutas, 2005), syntactic (e.g., Van Berkum et al., 2005), and semantic features of the upcoming utterances (e.g., Altmann & Kamide, 1999).

For example, Federmeier, McLennan, De Ochoa, and Kutas (2002) asked adult participants to listen to sentences that allowed them to make semantic predictions about the sentence-final words (e.g., *They wanted to make the hotel look more like a tropical resort. So, along the driveway, they planted rows of...*). At the end of each sentence, participants heard either an expected (e.g., *palms*) or an unexpected word (e.g., *pinos*), and their Event Related Potentials (ERPs) were recorded. Hearing an unexpected word evoked a strong positive potential, which is typically interpreted to indicate surprise. Hearing an expected word did not have such effect. This suggests that participants generated predictions about the semantic features of the upcoming words, and showed a clear surprise effect when these predictions were violated (similar results have been found for reading; Federmeier & Kutas, 1999).

Furthermore, there is evidence that prediction is also used by developing speakers (e.g., Borovsky, Elman, & Fernald, 2012; Nation, Marshall, & Altmann, 2003). Mani and Huettig (2012) used eye-tracking to investigate whether toddlers engage in predictive processing during comprehension. On each trial, participants were presented with two images of familiar objects, and heard a sentence that was either neutral or predictive of the sentence-final word. Importantly, one of the images was a target image that depicted the sentence-final word, and the other one was a distractor. Participants' predictive fixations to the target image were

measured, i.e. fixations in the time window prior to hearing the sentence-final word. The study found that participants made more predictive fixations when hearing predictive than neutral sentences, indicating that toddlers readily engage in linguistic prediction.

Further evidence for the use of the simulation mechanism in language comes from research showing that aspects of the production system are activated during speech perception (for a review, see Pickering & Garrod, 2013). Behavioural studies have found that perceiving language facilitates imitative production: participants are faster to pronounce a syllable after hearing the same syllable than after a tone. Interestingly, such imitative production can be almost just as fast as production of a pre-prepared syllable (Fowler, Brown, Sabadini, & Weihs, 2003; Porter & Castellanos, 1980; Porter & Lubker, 1980). Moreover, there is evidence from neurophysiological paradigms. In one study, Transcranial Magnetic Stimulation (TMS) was used to induce motor-evoked potentials (MEPs) in participants' lip muscles, while they were subjected to the following conditions: listening to speech, listening to non-speech sounds, observing lip movements, and observing eye and brow movements. MEPs were compared between these conditions, and it was found that listening to speech and observing lip movements were associated with an increase in lip muscles' potentiality, as compared to listening to non-speech sounds and observing face movements (Watkins, Strafella, & Paus, 2003). This suggests that speech articulators are activated when perceiving speech, but not when perceiving other auditory stimuli (see also Fadiga, Craighero, Buccino, & Rizzolatti, 2002). Other studies showed that perceiving speech elicits activation also in the cortical areas that are otherwise responsible for speech production (Pulvermüller et al., 2006; Wilson, Saygin, Sereno, & Iacoboni, 2004).

8.3 Investigating the Role of Production System in Simulation

These findings give some credence to the idea that a production-based simulation mechanism is routinely involved in language comprehension: they suggest that people engage in linguistic prediction, and that the language production system is active while perceiving language. However, before simulation can be considered a candidate mechanism for promoting automatic linguistic imitation, one important assumption of the language simulation account needs to be tested. More specifically, note that the findings discussed in the previous section

do not demonstrate a causal relationship between engaging the production system and the ability to generate predictions. This is a critical assumption of the language simulation account, and yet it remains largely unexplored.

There is some evidence that production skills are positively associated with linguistic prediction (Federmeier, Kutas, & Schul, 2010; Mani & Huettig, 2012), but due to the correlational nature of these studies they do not allow inferences about causality. To this date, only one study showed that production is engaged specifically in prediction. D'Ausilio, Jarmolowska, Busan, Bufalari, and Craighero (2011) found that the motor-evoked potential in tongue muscles was increased when participants expected to hear a tongue-produced phoneme as compared to a lip-produced phoneme. However, this shows that the production system is involved in prediction of low-level speech sounds, and does not provide any insight into whether this is the case with more complex language units. Moreover, it does not demonstrate that the activation of production is essential for successful comprehension (as it should be because of its use in inverse and forward models).

In an attempt to bridge this gap, in Chapter 2 of this thesis I present three experiments testing the assumption that the language production system is used for generating predictions. In these experiments, participants read sentence contexts that either were or were not predictive of the sentence-final word, and made a judgment about this word. To manipulate the engagement of the production system, we asked participants to read the contexts either silently or aloud. We expected that engaging production by reading the contexts aloud should enhance the effects of prediction on participants' word judgments, i.e. participants should generate stronger predictions about the sentence-final word in highly predictive contexts (as compared to non-predictive contexts), but crucially, this effect should be enhanced by reading aloud. This would provide evidence that engaging the production system affects the ability to predict the upcoming utterances, therefore lending some support to the idea that the simulation mechanism is routinely involved in language comprehension.

9 TEMPORAL ADAPTATION

People are able to time their actions to the rhythms around them. Interestingly, these rhythms do not need to be explicit. Sometimes, people adjust the timing of their actions to the temporal

patterns that are hidden within the actions performed by others. This ability is obviously critical for strictly rhythmic joint actions like musical performance, dance, or some group sports. But interestingly, some of the non-rhythmic actions might also be governed by the automatic mechanisms of rhythmic organisation.

In the following sections, I focus on one such mechanism, i.e. temporal adaptation, which is an ability to adopt features of an external rhythmic pattern. I review evidence that temporal adaptation might lead agents to spontaneously imitate temporal aspects of each other's behaviour. Finally, I argue that although this mechanism has been evidenced mostly with regards to continuous rhythmic actions, it is likely to affect also other types of actions, and it might be responsible for some instances of imitation observed in discrete non-rhythmic actions.

9.1 Sensorimotor Synchronisation

When perceiving a rhythmic sequence in their environment, people often attempt to synchronise with it various features of their behaviour. This ability has been studied under the name of sensorimotor synchronisation, and it has been shown to prevail across various contexts (for reviews, see Pressing, 1999; Repp, 2005, Repp & Su, 2013).

To begin, people are able to unilaterally adjust their actions to an unresponsive external rhythm. This type of sensorimotor synchronisation has been typically studied in laboratory set-ups where a participant is instructed to synchronise her motor movements with an externally-controlled pacing sequence. Success at the task is estimated using several indices, including the variability of the intervals between consecutive movements, the variability of the intervals between the movements and the units of the sequence, the mean length of these intervals. Importantly, the degree to which the participant is able to synchronise might range from perfect synchrony (where the movements and the sequence are aligned in all aspects), to no synchrony at all (where the movements and the sequence are temporally unrelated). In most cases, some imperfect synchronisation is achieved. For example, a participant might fail to execute her movements in synchrony with the sequence, but adjust the average pace of her movements to match to the pace of the sequence.

In this type of sensorimotor synchronisation studies, participants perform their movements as a part of a rhythmic action, i.e. an action where the temporal organisation is of primary importance to the action goal. For example, consider finger tapping, which is a commonly used task in this type of research (Repp, 2005). In a typical finger tapping study, a participant is asked to tap her index finger in synchrony with a metronome, and the response speed and duration of the taps are measured. Thus, finger tapping is performed as a strictly rhythmic action: the only purpose of tapping is to produce a certain rhythmic sequence, and the temporal structure of this sequence is critical to the success at the task. Some other tasks used to investigate unilateral synchronisation also involved motor movements, e.g., swinging a pendulum (Lagarde & Kelso, 2006), bending a knee (Ohtsuki & Kanehisa, 2011), rocking in a rocking chair (Demos, Chaffin, & Marsh, 2010), and drumming (Kirschner & Tomasello, 2009). But crucially, these movements were performed as rhythmic actions. Across these different tasks, sensorimotor synchronisation studies have found that people are able to unilaterally adjust various aspects of their actions to the external rhythm, and that they are largely successful at doing so even if the pacing sequence is irregular or perturbed (Repp, 2005).

However, sensorimotor synchronisation can also be a bilateral process. This type of synchronisation can be observed in social interactions, where both agents are able to adjust to their partner. For instance, musicians playing a duet are likely to monitor each other's actions and to mutually adjust various temporal aspects of their performance to achieve the desired level of synchrony (e.g., when one of them falls behind the tempo, the other slows down). Some studies attempted to investigate bilateral synchronisation using set-ups involving a human participant and a responsive virtual agent. For example, Repp and Keller (2008) asked participants to synchronise their finger tapping with a sequence produced by a virtual agent programmed to respond to participants' tapping in a certain way. The agent's behaviour varied between conditions, ranging from adaptive (i.e. modelled on typical human behaviour) to counter-adaptive responses (i.e. modelled to be opposite to the typical human behaviour). The study found that participants were able to maintain synchrony in all conditions, even when the virtual agent was behaving in a counter-adaptive manner (see also Kelso, de Guzman, Reveley, & Tognoli, 2009; Vorberg, 2005).

Other studies looked at interactions between two human participants. Konvalinka, Vuust, Roepstorff, and Frith (2010) asked pairs of participants to maintain a beat while hearing different types of auditory feedback. There were four within-participants conditions: in computer condition, the auditory feedback heard by both participants was a computer-generated beat; in uncoupled condition, both participants heard the sounds generated by their own tapping; in unidirectional condition, both heard the sounds generated by one of them; and in bidirectional coupling, both heard sounds generated by each other. The study found that when participants were able to hear each other's taps, they achieved some degree of synchronisation by mutually adjusting the length of the intervals between consecutive taps. Strikingly, they were similarly successful at synchronising with the stable and predictable computer-generated beat and with the more irregular and less predictable human partner (see also Demos, Chaffin, Begosh, Daniels, & Marsh, 2012). This suggests that participants used the ability to adjust their actions to each other to make up for the fact that the signal produced by a human partner was more noisy. The finding that interacting partners are capable of bilateral sensorimotor synchronisation was subsequently replicated (e.g., Nowicki, Prinz, Grosjean, Repp, & Keller, 2013; Pecenka & Keller, 2011).

9.2 Unintentional Synchronisation in Social Interactions

Although in many natural settings synchronisation is directed by an explicit goal to coordinate with others (e.g., Keller & Appel, 2010; Schmidt et al., 1990; Wing & Woodburn, 1995), people may also adjust aspects of each other's rhythmic actions without intentional control. Indeed, in some social situations it is difficult not to fall into the perceived rhythm (e.g., consider an audience trying to sit still at a jazz concert), and multiple studies have shown that unintentional sensorimotor synchronisation occurs commonly during interactions. In what is now a classic study, Schmidt and O'Brien (1997) asked pairs of participants to swing pendulums while sitting side by side. Participants could not see one another, except the last 12 seconds of each trial. The analysis found that during these periods their movements were more often performed in-phase or antiphase, as compared to when they could not see each other. Crucially, this occurred even though participants were instructed to maintain their individual tempo, suggesting that synchronisation in this task was carried out unintentionally.

Similar results were obtained by Richardson, Marsh, and Schmidt (2005) who asked participants to swing pendulums while engaged in a puzzle-solving task. To rule out an intention-based explanation, pendulum-swinging was framed as a distraction task. Participants performed the experiment under three conditions: in visual contact condition, they were able to observe each other; in verbal interaction condition, they were allowed to converse while engaged in the task, but were told not to look at each other; in verbal and visual condition, they were able to both converse and observe each other. Importantly, when participants were able to see each other, they spontaneously synchronised aspects of their movements to a higher extent than when they did not have visual contact. Further studies have demonstrated that unintended sensorimotor synchronisation occurs also in other joint rhythmic actions, e.g., musical performance (Clayton 2007; Lucas, Clayton, & Leante, 2011), joint finger tapping (Konvalinka et al., 2010; Oullier, de Guzman, Jantzen, Lagarde, & Kelso, 2008), and rocking in rocking chairs (Richardson et al., 2007).

9.3 Two Perspectives on the Mechanisms of Unintentional Synchronisation

The research on sensorimotor synchronisation has been guided by two distinct theoretical views, each following different assumptions, using different methodologies, and interested in different types of actions, i.e. the information-processing perspective and the dynamical systems perspective. Importantly, accounts informed by these perspectives have proposed mechanisms to explain sensorimotor synchronisation in general, and unintentional synchronisation with others in particular (for reviews, see Pressing, 1999; Schmidt, Fitzpatrick, Caron, & Mergeche, 2011; Repp, 2005).

First, a vast body of research has been guided by the information-processing perspective. Studies following this perspective tend to focus on rhythmic actions that are organised into discrete time series (e.g., finger tapping). In this view, sensorimotor synchronisation can be explained by certain cognitive mechanisms that allow agents to represent and integrate one's own actions with the actions of others (e.g., Keller, Novembre, & Hove, 2014). For example, van der Steen & Keller (2013) proposed two such mechanisms: adaptation and anticipation. Here I focus on the former, because of the large body of research suggesting its causal role in unintentional sensorimotor synchronisation (Repp, 2005; Repp & Su, 2013).

In the information-processing perspective, temporal adaptation is a mechanism of error correction which compares the rhythm of a perceived action with an internal timekeeper, and makes relevant adjustments to the rhythm produced by the timekeeper (van der Steen & Keller, 2013). The timekeeper is an internal process that generates pulses used to initiate motor commands for one's own actions (Wing & Kristofferson, 1973). By making corrections to the timekeeper, agents are able to temporally adapt their actions to the actions of others. Adaptation can be achieved by two types of error correction: first, agents might intentionally adjust the period of the timekeeper to match the period of the perceived actions; second, agents may adjust the intervals between the pulses of the timekeeper, effectively correcting its phase (Repp, 2005). Critically, such phase correction has been demonstrated to occur outside of intentional control, and to lead to instances of unintentional synchronisation. For example, Repp (2002) asked participants to synchronise with an allegedly isosynchronous rhythm to which either subliminal or supraliminal phase changes were introduced. Participants heard the rhythm in their headphones and were instructed to tap along using one of the keys on a MIDI keyboard. Crucially, they were explicitly instructed to ignore any perturbances in the rhythm. The study found that where phase shifts were introduced in the sequence, participants corrected the phase of their subsequent tap in response to the shift. Strikingly, they did so despite the instructions to ignore perturbances, and both when the shift was subliminal and supraliminal, suggesting that the phase correction was automatic. These and other findings from research in the information-processing perspective suggest that unintentional synchronisation results from a temporal adaptation mechanism, which involves an automatic correction of the phase of one's own actions in response to the perceived rhythm (for further evidence for automatic phase correction, see the reviews by Repp, 2005; Repp & Su, 2013).

The second theoretical perspective considers the processes of sensorimotor synchronisation from the point of view of dynamical systems theory. Studies in this perspective are concerned primarily with continuous rhythmic actions (e.g., swinging pendulums). This approach assumes that social interactions involve activation of biological subsystems within and between the interacting agents. Crucially, these subsystems become synchronised as a result of universal principles of dynamic self-organisation that regulate the activity of oscillating systems (e.g., Schmidt & Richardson, 2008). Specifically, the dynamical systems perspective

proposes that this synchronisation is achieved by an automatic mechanism that leads agents to temporally adapt to each other, i.e. entrainment.

Entrainment is hypothesised to be an instance of the coupling of rhythmic oscillators that is routinely observed in some mechanical and biological systems (Haken, Kelso, & Bunz, 1985). For example, two clocks hanging next to each other tend to synchronize because they are mechanically connected (Huygens, 1673/1986), and large groups of fireflies synchronize their flashing because each individual perceives the behaviour of others (Hanson, 1978). According to the principles of dynamic self-organisation, mechanical coupling or perceptual information uptake is sufficient to allow for a gradual synchronisation of the activity of two oscillating systems. Thus, two interacting agents who are able to perceive the actions of each other should mutually adapt merely due to the dynamic self-organisation. Importantly, this should happen particularly for actions that are performed in a continuous, oscillatory manner.

In a study by Richardson and colleagues (2007), pairs of participants rocked in rocking chairs while either facing each other (focal condition), sitting side by side (peripheral condition), or facing the other way (no information condition). Moreover, each participant was instructed to maintain their individually preferred tempo. Consistently with the assumption of the dynamical system perspective, participants who were able to observe each other unintentionally entrained their actions. Moreover, their entrained movement dynamics resembled a coupled oscillator system, i.e. they locked either on performing the movements in-phase or antiphase. Entrainment has been evidenced in multiple other studies (for reviews, see Marsh et al., 2009; Schmidt & Richardson, 2008; Schmidt et al., 2011). Together, research in the dynamical systems perspective suggests that interacting agents might automatically adapt some temporal aspects of their actions due to universal principles of dynamic self-organisation.

To sum up, findings from studies following both the information-processing and the dynamical systems perspective consistently show that (some form of) an automatic adaptation mechanism guides the behaviour of interacting agents and promotes unintentional synchronisation between them. Although these two perspectives are currently associated with different theoretical assumptions, methodological approaches and somewhat different types of actions, it has been suggested that they will eventually be reconciled (Pressing, 1999; Repp, 2005).

Moreover, findings from both have been integrated in common theoretical frameworks of social coordination (e.g., Knoblich et al., 2011). In the following sections, I adopt this view and consider entrainment and phase correction to both be forms of an automatic temporal adaptation mechanism.

9.4 Temporal Adaptation in Non-Rhythmic Actions

Note that research on sensorimotor synchronisation has investigated adaptation mostly with regards to rhythmic actions (see Schmidt & Richardson, 2008; Repp, 2005, Repp & Su, 2013). But what constitutes a rhythmic action? In a sense, all recurrent motor actions can be conceptualised as rhythmic because they are describable in terms of time-series. Yet, some actions are considered to be rhythmic, whereas others are not, despite the fact that such actions might sometimes be very similar to each other. For example, finger tapping is commonly used to investigate synchronisation and is assumed to be a rhythmic action, but button pressing is used to investigate motor action as a discrete event and its rhythmic organisation across trials is often ignored (as I will argue in the following sections). Arguably, the criteria used in the literature for categorising an action as rhythmic can be generally unclear (e.g., scratching and feeding behaviour are sometimes considered to be rhythmic; Pearson, 2000). To clarify the difference between rhythmic and non-rhythmic actions for the needs of this thesis, I propose to distinguish such actions based on the criterion of the action goal (cf. Keller et al., 2014).

According to this distinction, rhythmic actions are engaged in order to produce a rhythmic pattern, and their temporal structure is necessitated by this goal. For example, in finger tapping the recurrent taps are organised in time so that they form a certain rhythmic group or constitute a tempo. Conversely, non-rhythmic actions are not concerned with producing a rhythm. Although they may also be organised in time in a regular manner, their temporal structure is not of primary importance to the action goal. For example, walking is repetitive motor action that often shows a high degree of regularity (i.e. people tend to walk in a certain pace and maintain a similar distance between steps). But crucially, the goal of walking is to move to a given location, and not to produce a rhythm with one's steps. Thus, according to the distinction proposed here, walking is a non-rhythmic action in a sense that its rhythmic self-organisation is not goal-directed.

Studies on sensorimotor synchronisation have somewhat neglected the possibility that temporal adaptation might occur in non-rhythmic actions. In particular, phase correction response has been evidenced mostly for finger tapping tasks where the participant was instructed to synchronise with the pacing sequence (e.g., Repp, 2002). Spontaneous temporal entrainment has also sometimes been investigated with tasks where participants were asked to maintain a given rhythm (e.g., Sofianidis, Hatzitaki, Grouios, Johannsen, & Wing, 2012; Richardson et al., 2007). But interestingly, there is some evidence to suggest that interacting agents might entrain their actions also when engaged in non-rhythmic joint actions.

For instance, Issartel, Marin, and Cadopi (2007) found that people unintentionally entrain the frequencies of improvised movements. In this study, participants were instructed to freely move their forearms while standing side by side. Importantly, they were explicitly asked to ignore the movements of the other person. Despite these instructions, participants preferred movement frequencies became partially entrained when they were able to see each other. Moreover, temporal aspects of walking might also be entrained. Van Ulzen, Lamoth, Daffertshofer, Semin, and Beek (2008) asked pairs of participants to walk next to each other on a treadmill. Participants were instructed either to walk in a comfortable pace, or to synchronise in-phase or antiphase with the other person. Importantly, evidence for phase locking was found in the free walking condition, suggesting that participants became unintentionally entrained even when they were not given a goal to maintain a rhythm (see also Van Ulzen, Lamoth, Daffertshofer, Semin, & Beek, 2010). Similar results were obtained by Zivotofsky and Hausdorff (2007) who found that participants spontaneously synchronised their steps simply when asked to walk down the hall together (see also Zivotofsky, Gruendlinger, & Hausdorff, 2012).

10 CAN TEMPORAL ADAPTATION OCCUR IN DISCRETE NON-RHYTHMIC ACTIONS?

Together, these findings suggest that some form of automatic temporal adaptation might occur when agents are engaged in non-rhythmic actions. However, note that the studies reviewed in the previous section focused on actions that are continuous (or can be conceptualised as such). Thus, temporal adaptation has been shown to regulate interactions where agents perform discrete rhythmic actions (i.e. phase correction) or non-rhythmic actions that are continuous

(i.e. entrainment). But could it also affect interactions involving non-rhythmic actions that are discrete?

This question is important not only for basic scientific reasons. A number of controlled experimental paradigms employ discrete non-rhythmic actions to study the mechanisms of social coordination and joint action. However, researchers using these paradigms typically investigate high-level mechanisms, and tend to ignore simpler low-level explanations. For instance, a joint version of the classic Simon task has been used to argue that agents co-represent each other's actions (Sebanz, Knoblich, & Prinz, 2003). But recently it has been suggested that the findings obtained from this task can be explained by much simpler attentional processes (Dolk, Hommel, Prinz, & Liepelt, 2013; Dolk, Hommel, Colzato, et al., 2014; for a similar argument in relation to the joint Flanker task, see Dolk, Hommel, Prinz, & Liepelt, 2014). Thus, a recent debate opened up a possibility that some commonly used experimental paradigms may be affected by previously unconsidered low-level mechanisms. Importantly, automatic temporal adaptation could be one such mechanism, should it be found to affect the type of discrete non-rhythmic actions involved in these tasks.

Furthermore, imitation research might also benefit from investigating whether automatic temporal adaptation is involved in discrete non-rhythmic actions. At times, automatic adaptation leads agents to spontaneously imitate various temporal features of the each other's actions. Some forms of automatic temporal adaptation have been suggested to result in perfect synchrony where agents perform the same action at the same time as others (e.g., audiences clapping in unison; Neda et al., 2000). On other occasions, adaptation can promote partially synchronised interactions where similar actions become entrained to the same tempo, but are not performed at the same time (e.g., leg swinging in antiphase; Schmidt et al., 1990). Importantly, it is also possible that automatic temporal adaptation may lead agents to imitate some general temporal characteristic of each other's actions (e.g., imitation of speech pace; Webb, 1969).

10.1 Investigating the Role of Automatic Temporal Adaptation in Imitation

To sum up, automatic temporal adaptation has been shown to affect motor actions independent of (e.g., Repp, 2000) or even against intentional control (e.g., Konvalinka et al., 2010), leading

the interacting agents to unintentionally imitate various temporal aspects of each other's actions. Moreover, it has been demonstrated to occur in both rhythmic and non-rhythmic actions. However, it remains to be tested whether automatic temporal adaptation affects interactions that involve a specific type of non-rhythmic actions, i.e. movements performed in a discrete, non-continuous manner.

In Chapter 3, I present three experiments that investigate this possibility in relation to a specific instance of imitation. In a recent study, Pfister, Dignath, Hommel, and Kunde (2013) asked pairs of participants to engage in a joint button pressing task. One participant acted as a leader and produced either a short or a long press in response to a cue, while the other participant acted as a follower and was instructed either to perform the same (e.g., short – short) or the opposite press as the leader (e.g., short – long). The study found that leaders initiated their actions faster in the condition where the followers responded with the same press, as compared to where they responded with the opposite press. The authors interpreted these findings as evidence for a high-level co-representation of partner's actions, in line with the literature on compatibility effects and the ideomotor theory (e.g., Hommel, Müsseler, Aschersleben, & Prinz, 2001). They suggested that leaders anticipate the response of their partners, and that this facilitates action execution when the followers' action is anticipated to be identical.

However, the study did not control for the fact that participants were able to freely observe each other. Crucially, the study also found that the followers' showed a temporal pattern that corresponded to that of the leaders', i.e. followers were faster when responding with the same than the opposite type of press. Thus, these findings could be potentially explained by automatic temporal adaptation: the leaders might have adapted their response pace to the followers', and become fast when the followers were fast. The experiments presented in Chapter 3 investigated this hypothesis by manipulating whether the leaders could observe the followers. If the temporal pattern of leaders' actions was caused by temporal adaptation, it should no longer resemble the followers' pattern in the conditions where the leaders could not observe the followers. Moreover, the experiments manipulated the followers' response pace so that it would be effectively reversed. If leaders adapt to this new pattern (while being able to observe the followers), this would provide further evidence that automatic temporal

adaptation might promote imitation in discrete non-rhythmic actions like the ones employed in this task.

11 UNCONSCIOUS GOAL TO AFFILIATE

Intentional goal-pursuit plays an important role in initiating and directing human behaviour. However, in some situations, and particularly during social interactions, we may find ourselves doing something that we did not quite intend. Do we shake somebody's hand because we planned to? Do we laugh at a joke, or smile back at a smile because of conscious deliberation? Sometimes we may, but these and other social behaviours can also be initiated automatically. Over the last two decades, research in social psychology has amassed evidence that many of the behaviours that occur during social interactions do not require intention, and that the list of such behaviours is much longer than we used to think.

Imitation is believed to be one of such behaviours. But if it is not intention, then what motivates people to imitate? In the following sections, I argue that imitation might emerge as a result of an unconscious pursuit of social goals. Previous research showed that imitators benefit from copying others: imitation makes them more likeable in the eyes of others, improves their social interactions, and encourages the ones with whom they interact to act in a cooperative way. In light of these findings, it has been suggested that imitation is a means of achieving a goal to have successful social interactions with others (Chartrand & Jeffers, 2003; Cheng & Chartrand, 2003; Lakin & Chartrand, 2003). However, the evidence for this account comes predominately from research on spontaneous imitation of motor behaviour, i.e. behavioural mimicry. Could other types of imitation also be motivated by the unconscious goal to affiliate? I propose it might be so, and further argue that the unconscious pursuit of this goal could potentially explain some instances of linguistic imitation.

11.1 Theories of Conscious and Unconscious Goal-Pursuit

The idea that human behaviour is directed and regulated by a pursuit of goals is perhaps one of the most influential in psychology (for reviews, see Austin & Vancouver 1996; Elliot & Fryer 2008). In this view, actions are motivated by their results, or end-states. In other words, people engage in a given behaviour because they want to achieve the end-state that can be

brought about by this behaviour (e.g., a change in their environment, a different internal state of their organism). A goal is a mental representation of this desired end-state and the behavioural routines that are needed to achieve it (Aarts & Dijksterhuis, 2000; Dijksterhuis & Aarts, 2011; Hull, 1931; Fishbach & Ferguson 2007; Skinner, 1953). Thus, pursuing a goal increases the potentiality of the corresponding behavioural routine. Critically, this may lead to the execution of this behaviour, which in some cases might be engaged automatically. There are two types of theories of goal pursuit that are important with regard to their views on automaticity of behaviour.

Traditionally, most theories assumed that behaviour is initiated and guided by a conscious choice of the individual (e.g., Bandura, 1986; Carver & Scheier, 1998; Deci & Ryan, 1985; Locke & Latham, 1990). In this view, people are aware of their desires, able to make a rational choice of whether to pursue a goal or not, and determined to act in order to bring about the desired end-state. Goal pursuit is intentional, and a conscious individual is capable of monitoring and controlling the behaviour at each stage, from action selection to completion. Simple motor actions, like reaching for a cup of coffee, can be conceptualised in terms of conscious goals. When an individual feels the desire to drink a sip of coffee, she might choose to extend her hand, grasp the cup, move it towards her mouth, and drink. In this example, the desired end-state is drinking coffee, and the preceding behavioural routine is engaged in order to achieve it. Importantly, both the goal and the execution of behaviour are monitored by conscious awareness, allowing the individual to alter or stop the action if she would wish to (e.g., the cup would be empty).

But recently, a very different view on human behaviour started to gain momentum. According to the theories of unconscious goal pursuit, behaviour can be triggered and executed independently of intention, and outside of conscious awareness (e.g., Bargh, Gollwitzer, Lee-Chai, Barndollar, & Trötschel, 2001; Moskowitz, Gollwitzer, Wasel, & Schaal, 1999; for reviews, see Dijksterhuis & Aarts, 2011; Huang & Bargh, 2014). In this view, the individual is unaware of the goal and is unable to detect or report its influence on her behaviour. Despite lacking the intentional component, unconscious goals function similarly to conscious ones, i.e. they organise attention, information processing, and behaviour so that they help to achieve the desired end-state. An active goal is sufficient to initiate a behaviour and run it to a completion,

and no intervention from the conscious individual is required. In this sense, the behaviour might be engaged automatically. For example, a desire to make friends could lead an individual to exhibit behaviours associated with a positive attitude towards others: smiling, keeping a short personal distance, being active in a conversation, etc. Crucially, these behaviours would occur unintentionally, as a result of the unconscious goal to affiliate with other people.

The two views on the nature of goal pursuit are not impossible to reconcile (Baumeister & Bargh, 2014). In fact, most of the accounts of unconscious goal pursuit acknowledge that many behaviours are guided by intentions (e.g., Bargh et al., 2001). Even the particularly strong formulations of these accounts do not claim that all is unconscious, although they may give primacy to the automatic production of behaviour (e.g., Huang & Bargh, 2014). However, given that the aim of this review is to discuss the automatic mechanisms of emergent imitation, in the next sections I will focus on the evidence that social behaviour is at times caused by the unconscious goal pursuit, and as such may be automatic.

11.2 Automatic Behaviours in Social Interactions

An automatic behaviour is one that is executed, and sometimes also selected and initiated, without intentional control (Bargh & Chartrand, 1999; Bargh, Schwader, Hailey, Dyer, & Boothby, 2012). Many well-rehearsed motor routines (e.g., walking, shaking hands with others), skills (e.g., writing, skiing), and simple repetitive actions (e.g., pumping a bicycle tire, screwing in a screw) are commonly believed to be at least to some extent automatic (see Anderson, 1982). What is more surprising, perhaps, is that higher-order, complex social behaviours can also be engaged automatically. Many researchers in social psychology believe that automatic social behaviours include mating, aggressive behaviour, cooperation, helping, and most importantly, imitation (for reviews, see Baumeister, Vohs, DeWall, & Zhang, 2007; Bargh et al., 2012; Huang & Bargh, 2014; Strack & Deutsch, 2004).

Besides anecdotal (e.g., Allport, 1937) and observational evidence (e.g., LaFrance, 1979), a considerable number of experimental studies demonstrated that people automatically imitate others during social interactions (for a review, see Chartrand & Lakin, 2013). For example, Chartrand and Bargh (1999) asked participants to engage in a photo description task together

with a confederate who posed as another participant. The confederate was instructed to either rub her nose or shake her foot during the interaction. The session was video-recorded, and the recordings were later analysed to see if participants imitated the target behaviour exhibited by the confederate. It turned out that they did: participants shook their foot more often when the confederate shook their foot than when she rubbed her nose, and vice versa. Crucially, they did not report being aware of the fact that they imitated the confederate or the behaviour they imitated. This suggests that participants did not intend to imitate and that they might have copied the behaviour of the confederate entirely unconsciously. Other experiments found that in a similar manner people imitate yawning (e.g., Platek, Critton, Myers, & Gallup, 2003), laughter (e.g., Provine, 2001), and specific mannerisms like pen-playing (e.g., van Baaren, Fockenberg, Holland, Janssen, & van Knippenberg, 2006). Together, these findings suggest that imitation might sometimes occur automatically during interactions with others.

Evidence for the automaticity of other social behaviours comes mostly from social priming studies (see Molden, 2014). In a typical social priming paradigm, participants are first presented with a stimulus designed to activate a mental construct related to the behaviour in question. Then, they engage in an interaction during which the behaviour is being measured. The final phase of a social priming study usually involves some measure of intentional control, in order to determine whether the observed behaviour was executed automatically. For example, Bargh et al. (2001) asked participants to construct sentences from words that were either related to the idea of cooperativeness (e.g., cooperative, fair, friendly) or neutral (e.g., salad, umbrella, city). Thus, participants were either primed to cooperate or not. Next, they played an economic game where they could share resources with the other person or keep the resources to themselves to maximise their own earnings. The study found that the group that was primed behaved in a more cooperative way (i.e. shared more of their resources) than the group that was not primed. Crucially, there was no difference in groups' self-reported intention to cooperate, as indicated by post-experimental questions that participants answered at the end

of the study. The authors interpreted this as evidence that the primed group engaged in cooperative behaviour without intentional control, i.e. automatically.⁶

11.3 What Elicits Automatic Social Behaviours?

The findings of the study described above are certainly fascinating and suggest that people might unintentionally engage in various social behaviours, including imitation. But if it is not the individual's intention to act, then what mechanism could elicit these behaviours?

In an early attempt to address this question, Dijksterhuis and Bargh (2001) proposed a direct “perception-behaviour expressway” that operates outside of conscious awareness, and leads to the production of automatic behaviours. They argued that automatic imitation of social behaviours might stem directly from the organisation of the cognitive system, rather than being a result of behavioural conditioning, or intention. According to this account, the overlap between perceptual and behavioural representations means that activation of the former spreads to the latter, resulting in an automatic tendency to engage in the perceived actions. Furthermore, a behavioural representation for an action can also be activated merely by thinking about performing this action, or through a concept that is related to it.

Dijksterhuis and Bargh argued that this account could explain cases of behavioural contagion that occur in social settings. For instance, yawning seems to be induced both by direct observation and by thinking about it. In one study, one group of participants watched a short video of other people yawning, whereas another group watched a video of people smiling (Provine, 1986). The percentage of participants who started yawning during the video was greater in the condition that involved watching yawns than smiles. Moreover, yawning was also induced by reading about it: another group of participants read an article about yawning, whereas a further group read about hiccupping. Similarly as with watching videos, reading

⁶ Note that some serious theoretical and methodological issues have been raised with regards to social priming paradigms (Loersch & Payne, 2016; Ramscar, 2016; for a recent meta-analysis addressing some methodological concerns, see Weingartner et al., 2016).

about yawning led to a higher percentage of participants who yawned than reading about hiccups. Therefore, social behaviours can be elicited by perceiving them or by activating the related concept. For example, reading adjectives related to the idea of cooperativeness activates the mental representations of behavioural routines associated with cooperation, which in turn leads to automatic execution of overt cooperative behaviour (Bargh et al., 2001).

Dijksterhuis and Bargh's (2001) account (and some other early accounts, e.g., Bargh et al., 2001) somewhat neglected the fact that people do not always behave as the situation dictates them. The selective nature of social behaviours, including those that are automatic, is better addressed by some more recent accounts. In Strack and Deutsch's (2004) dual-system model, social behaviours are directed by mental processes organised into the reflective and the impulsive system. The reflective system involves conscious awareness and intentional control, and therefore will not be discussed here. However, the impulsive system is more interesting from the point of explaining automatic imitation.

According to Strack and Deutsch, a behaviour may be automatically produced as a result of activating the relevant behavioural schema stored in the impulsive system. A behavioural schema is a mental construct comprising of three associated elements, i.e. a representation of the situational condition, a representation of the behavioural routine, and a representation of the consequences of behaviour. To activate a schema, it is sufficient to activate one of its elements, which can be achieved by the perceptual input from the environment. Thus, the representation of the routine for a given behaviour can be activated by observing this behaviour being performed by another person. Moreover, it can also be activated by observing the consequences of this behaviour, or by perceiving environmental cues that would activate the representation of a situational condition associated with this behaviour. For example, observing a conversational partner smile is likely to activate the behavioural routine for smiling, and particularly so if it occurs in a social setting associated with smiling (e.g., an informal chat with a colleague). However, activating a representation of the routine does not

always lead to the production of the behaviour – the individual will engage in overt behaviour only if the schema is activated above a certain threshold.⁷ But how is this threshold exceeded?

One possibility is that the activation threshold is lowered for behaviours that are compatible with the overall motivational orientation of the system, i.e. the motivation to avoid or to approach others. Imitation is likely to be compatible with the motivation to approach, because it has been shown to create liking, empathy, and affiliation, as well as increase interdependence and feelings of closeness between people (see Chartrand & Lakin, 2013). According to Strack and Deutsch, this orientation can be switched on by processing positive information or affect, and by perceiving or executing approach behaviours. Thus, people should engage in automatic imitation in the presence of factors that promote the more prosocial motivation to approach. This is consistent with findings such as that being prosocially oriented (e.g., van Baaren, Maddux, Chartrand, DeBouter, & van Knippenberg, 2003), and experiencing a positive affect (e.g., van Baaren et al., 2006) leads to imitation.

11.4 Imitation and the Unconscious Goal to Affiliate

The idea that a prosocial motivation might trigger automatic social behaviours is in agreement with studies suggesting that imitation might serve the unconscious goal to affiliate with others. For example, Lakin and Chartrand (2003) in two experiments showed that an active affiliation goal may elicit imitation during a social interaction. In the first experiment, participants were assigned to one of the three groups: a group that was primed with an unconscious goal to affiliate by reading words related to affiliation (e.g., *friend*, *affiliate*, *together*), a group that was given a conscious goal to affiliate by instructing them to get along well with the interaction partner, and a control group that was given no goal. Participants in each group watched a video

⁷ Note that Strack and Deutsch's and Dijksterhuis and Bargh's models both posit that the mental representation of a behaviour might be activated by the perception of relevant environmental cues. However, the activation threshold suggested by the former helps to explain why automatic behaviours are not always executed.

of another person who occasionally touched her face while doing clerical tasks (e.g., filing papers, answering the phone), and were secretly filmed to determine whether they would also touch their face. Importantly, the groups that were given a goal to affiliate imitated the face-touching behaviour to a greater extent than the control group, regardless of whether the goal was conscious or unconscious. When asked about the behaviour of the person in the video participants did not mention face-touching, which could suggest that they imitated it unconsciously. Thus, an active goal to affiliate encouraged participants to automatically imitate the behaviour they observed in their interaction partner.

The second experiment tested whether deactivating the goal to affiliate decreases its potential to elicit imitation. Participants were assigned to a group primed with an unconscious goal to affiliate or to a control group, and then interacted via a text-based computer chat with a person who behaved either in friendly or unfriendly manner. Chatting with a friendly partner was meant to satisfy the desire to affiliate with others, and thus deactivate the previously primed goal. Next, participants spoke face-to-face with another person who shook their foot during the conversation, and were covertly filmed to determine if they would imitate foot-shaking. Consistent with the hypothesis that an active affiliative goal elicits imitation, participants in the primed group engaged in more imitation than the control group, but not if the goal was deactivated by chatting with a friendly partner.

These findings have been interpreted as evidence that imitation in social interactions is driven by an unconscious goal to affiliate with other people (Chartrand & Jeffers, 2003; Lakin et al., 2003). Because humans evolved to be highly social animals, they have a strong basal need to belong and to seek positive relations with others (Baumeister & Leary, 1995; Brewer, 1991). This desire is represented in the motivational system by the goal to affiliate with other people. Although the affiliative goal might at times be pursued consciously, in most situations it remains unconscious, similarly to many other motivational impulses (cf. McClelland et al., 1989). The possible evolutionary origins of the affiliative goal would suggest that it is routinely activated in human social interactions (Lakin et al., 2003). However, its activation might be increased or decreased in certain types of social environments and in case of particular individuals (Chartrand & Jeffers, 2003). Various social behaviours might serve the affiliative goal by creating liking between people and smoothening social interactions.

Crucially, imitation has been suggested to be one of such behaviours, and this is for three reasons: first, imitation may be elicited automatically, which is consistent with the idea that it is driven by an unconscious goal; second, imitation has been shown to bring about positive social consequences for the imitator; third, the amount of imitative behaviour is increased during interaction where the goal to affiliate is likely to be highly activated.

11.5 Evidence that Imitation Is Elicited by the Goal to Affiliate

There is now considerable evidence for each of these claims. Imitation may be engaged automatically in social interactions, as demonstrated by studies where participants were probed for their awareness of the behaviour they imitated. For example, Chartrand and Bargh (1999) used a “funnelled” post-test interview asking increasingly specific questions about the experiment and the social interaction it involved. Importantly, in this and other similar studies participants did not report an intention to imitate, awareness that they engaged in imitation, or even of the partner’s behaviour that they imitated (e.g., Stel & Vonk, 2010; Stel et al., 2010). Further evidence for the automaticity of social imitation comes from studies that it can be induced by subliminally priming the affiliative goal (e.g., Lakin & Chartrand, 2003). In these studies, the stimuli that activated the goal to affiliate were presented outside of participants’ conscious awareness, suggesting that imitation was engaged automatically.

Furthermore, imitation is likely to serve the affiliative goal because it can bring various social benefits for the imitator (for reviews, see Chartrand & Lakin, 2013; Hove & Risen, 2009). Previous research found that imitators are liked by others. For example, early studies have observed that the amount of postural imitation is positively correlated with self-reported rapport between the interacting partners (e.g., Charney, 1966; LaFrance, 1979). In a more recent study, participants interacted either with a partner who imitated their posture and movements or with a partner who sat still and did not imitate. The imitator was rated by the participants as more likeable as compared to the non-imitating partner (Chartrand & Bargh, 1999).

Imitation also encourages people to engage in positive behaviours that can directly benefit the imitator. For example, participants in one study more often helped a confederate to pick up pens from the floor if she had imitated them during an earlier interaction (Van Baaren, Holland,

Kawakami, & van Knippenberg, 2004). In another study, passers-by on a street more readily helped a confederate who imitated them as compared to a confederate who did not (Guéguen, Martin, & Meineri, 2011). Similar results have been obtained with typically developing children who were more likely to help an experimenter who imitated them (Carpenter, Uebel, & Tomasello, 2013), and with children diagnosed with Autism Spectrum Disorder who responded more positively to imitators than to non-imitating adults (Nadel, 2002; Field, Nadel, & Ezell, 2011; for a review, see Contaldo, Colombi, Narzisi, & Muratori, 2016).

Further evidence that imitation is elicited by the goal to affiliate comes from studies showing that people engage in more imitation when they have a strong desire to get along well with others. This desire might stem from individual differences. For instance, Chen and Chartrand (2003) demonstrated that people who are strongly motivated to maintain a positive social image engaged in more imitation than those who did not have this motivation, and that they did so particularly in situations where it was important to leave a good impression. Similarly, in another study participants with a strong sense of connection to others tended to imitate more, both when this attitude was induced by the experimenter and warranted by their cultural background (van Baaren et al., 2003).

However, the desire to affiliate is also stronger when interacting with members of one's social group, as opposed to out-group individuals. Yabar, Johnston, Miles, and Peace (2006) found that non-Christian participants imitated the face-touching behaviour of a confederate to a greater extent when the confederate was identified as non-Christian than Christian. Strikingly, the tendency to selectively imitate in-group members is already observable in very young children. For example, there is some evidence that 14-month-old infants more often imitate a model who speaks their native language than of a model who speaks a foreign language (Buttelmann, Zmyj, Daum, & Carpenter, 2013). Other studies suggest that the tendency to imitate in-group members emerges at the age of 3-years-old (Howard, Henderson, Carrazza, & Woodward, 2015; van Schaik & Hunnius, 2016; cf. Krieger, Möller, Zmyj, & Aschersleben, 2016). Finally, the goal to affiliate might also be temporarily activated by being socially excluded. Lakin, Chartrand and Arkin (2008) showed that participants who were ignored by other players during a brief computer-based game engaged in more imitation in a subsequent interaction, as compared with participants who were not ignored.

12 LINGUISTIC IMITATION AND THE DESIRE TO AFFILIATE

Together, these findings suggest that the tendency to imitate one's interaction partner is dictated by an unconscious goal to affiliate. However, the evidence for this idea comes almost exclusively from studies involving motor behaviour (e.g., mannerisms, facial expressions, motor actions). And yet, imitation is not limited to motor behaviour, but also occurs in language. Could the desire to affiliate with others be responsible for linguistic imitation?

According to Communication Accommodation Theory (CAT), convergence in language may indeed be guided by a motivation to affiliate with the conversational partner (Giles & Coupland, 1991; Giles, Mulac, Bradac, & Johnson, 1987). This theory assumes that accommodating to the verbal and non-verbal patterns used by another speaker is a sign of a positive attitude towards them, and that linguistic imitation is one of the strategies that helps to create liking and decrease social distance between speakers. There is a number of different factors that modulate the degree to which people imitate each other's language, ranging from personality traits (e.g., Natale, 1973) to in-group versus out-group identity (e.g., Giles, 1973). Crucially, these factors might interact in a complex way and be further affected by the communicative intention and various other goals. For example, the degree of phonetic imitation might be simultaneously affected by speaker's gender, conversational role, and intention to imitate (Pardo, 2006; Pardo, Jay, & Krauss, 2010). Most importantly, many of the predictions derived from CAT are consistent with the idea that imitation is driven by the unconscious goal to affiliate.

First, both CAT and the affiliative goal account predict that people who have a strong motivation to be positively evaluated by others will imitate more. In support of this, Natale (1973) showed that participants in an interview imitated the interviewer's vocal intensity. However, more imitation was associated with participants' self-reported need for social approval (measured by their tendency to report that they are similar to social norms).

Second, both accounts predict that people will imitate more when interacting with partners who belong to a desirable social group. This is supported by evidence from studies investigating the role of social status for linguistic imitation. For example, an analysis of the recordings from a television talk-show found that the degree of phonetic convergence between the host and the guests was greater with high-status than low-status guests (Gregory &

Webster, 1996). One possible interpretation of this finding is that the desire to affiliate is particularly strong towards members of a desirable high-status social group, which encouraged more imitation of the phonetic aspect of language.

Other studies found that a positive attitude towards a social group leads to more linguistic imitation when interacting with a member of this group. For instance, Babel (2010) asked participants who spoke a New Zealand English dialect to shadow a speaker of Australian English. Participants who had a more positive implicit attitude towards Australians (as measured by an Implicit Association Test; Greenwald, McGhee, & Schwartz, 1998) were more likely to accommodate to the other speaker. Importantly, the fact that the attitudes were implicit and that participants were not explicitly instructed to imitate suggests that imitation was engaged automatically, which gives credence to the idea that it was elicited by an unconscious goal to affiliate. Similar results have been obtained from studies where participants interacted with an attractive (e.g., Babel, 2012), desirable (e.g., Lev-Ari, 2015), or likable speaker (e.g., Balcetis & Dale, 2005).

Third, more imitation should be observed between people belonging to the same, as opposed to different social groups. Indeed, there is evidence that linguistic imitation is affected by the accent-indexed social identity of the interacting speakers. For example, Kim, Horton, and Bradlow (2011) measured phonetic convergence within pairs comprising two native speakers of American English, and mixed pairs comprising a native speaker and a non-native speaker. Pairs of native speakers converged more than mixed pairs. However, this was true only if both speakers in the native pair used the same accent of American English. If speakers used different accents, they did not show higher convergence than mixed pairs. This suggests that people engage in more imitation when interacting with a speaker that can be identified as belonging to the same social group. Conversely, the amount of linguistic imitation might be decreased when interacting with a speaker who distances themselves from one's own social group (e.g., Bourhis & Giles, 1977).

12.1 Investigating the Social Consequences of Linguistic Imitation

As shown, there is considerable evidence that people engage in more linguistic imitation when they have a strong desire to affiliate, either due to their own or the partner's characteristics

(e.g., Natale, 1973). Moreover, several studies have found that people might imitate language without any intention to do so (e.g., Pardo, 2006), and for reasons that slip their conscious awareness (e.g., Babel, 2010). Together, these findings suggest that imitation of language, similarly to imitation of motor behaviour, might be elicited by an unconscious goal to affiliate. However, one crucial assumption of this account remains to be demonstrated: if linguistic imitation does indeed serve the affiliative goal, then engaging in imitation should help imitators to improve their relations with others.

To this date, the evidence in support of this hypothesis does not allow inferences about the causal relationship between linguistic imitation and the quality of the relation with the other speaker. For example, correlational studies have found that high language style matching is related to relationship stability (Ireland & Pennebaker, 2010), and that people who use similar language more often cooperate with other (Scissors, Gill, & Gergle, 2008). But unfortunately, these studies did not manipulate, but merely observed the amount of linguistic imitation between speakers. Thus, the causal relationship between imitation and the other variables remains undetermined. Although some other studies did attempt to manipulate the amount of linguistic imitation, they did not properly control for other factors that might have affected the relation between the imitator and the imitated partner. For example, in one famous study a waitress was asked to either repeat the order back to her customer or to simply acknowledge it (van Baaren, Holland, Steenaert, & van Knippenberg, 2003). The amount of money she received in tips was greater in the imitation (repetition) condition, as compared to the other one. Importantly, this paradigm did not control for the vast differences between these two conditions that could be the true source of the observed effect (e.g., more words spoken when repeating vs. acknowledging, possible differences in motor behaviour). Other existing experiments suffer from similar methodological shortcomings (e.g., Müller, Maaskant, van Baaren, & Dijksterhuis, 2012).

In Chapter 4 of this thesis I therefore present three controlled experiments that investigated this assumption with regard to imitation of lexical choices. In the experiments, pairs of participants engaged in text-based picture-naming task, during which their conversation was manipulated so that their partner appeared either to imitate (i.e. use the same words for pictures) or counter-imitate them (i.e. use different words). Next, participants evaluated the

partner they interacted with and the interaction itself. Finally, to complement the self-report evaluation with a behavioural measure of the relation with the partner, participants engaged in a short decision making game where they could cooperate or compete with their partner. If people engage in linguistic imitation in order to foster their relationships with others, participants who were imitated during the task should more positively evaluate their partner and the interaction, as well as exhibit a more cooperative behaviour in the game than those who were counter-imitated.

13 A CASE FOR CROSS-EXAMINING THE MECHANISMS OF EMERGENT IMITATION

In the preceding sections of this review, I argued that imitation might emerge as a result of several automatic mechanisms that are involuntarily engaged when interacting with others. I discussed three such mechanisms, i.e. simulation, temporal adaptation, and the unconscious goal to affiliate. Moreover, I presented the existing evidence for the engagement of these mechanisms during social interactions and for their role in promoting imitative behaviours. Crucially, note that in case of each mechanism, the evidence tends to focus on studies into a single imitative behaviour. More specifically, the simulation mechanism has been widely investigated with regards to simple motor movements, and the attempts to link it to language are relatively rare and recent. Temporal adaptation has been evidenced for continuous actions, while the possibility that it might lead to imitation in discrete non-rhythmic actions has been neglected. Similarly, social psychology investigated the affiliative goal account in relation to behavioural mimicry, but some key assumptions of this account remain unexplored with regard to linguistic imitation. As a result, each of these mechanisms is often considered to be confined to a single type of imitative behaviour.

However, to convincingly argue that a given mechanism explains only one type of imitation, there would need to be negative evidence showing that this mechanism is not involved in other imitative behaviours. The current literature does not provide such evidence. I propose that this situation should be addressed by cross-examining the mechanisms of emergent imitation, i.e. conducting empirical studies to test whether each mechanism could be capable of explaining the types of imitation that are currently considered to be unrelated to it. In support of this proposition, I now turn to briefly discuss the theoretical arguments and empirical findings that

suggest that some of these mechanisms might be responsible for more than one imitative behaviour.

To begin, some theoretical arguments are convergent with the idea that the simulation mechanism might play a causal role in multiple imitative behaviours. Specifically, the perception-action link, which constitutes an important part of the simulation mechanism, has been proposed to extend beyond automatic imitation of simple motor movements. Heyes (2011) suggested that the perception-action link might have a more general cognitive application, and that the controlled experimental paradigm used to investigate automatic imitation could be treated as a laboratory model for other forms of imitation, including the imitative behaviours that can be observed in natural social interactions. Consistent with this are some earlier claims made by the researchers in the field of behavioural mimicry. For example, Chartrand and Van Baaren (2009) proposed that mimicry and automatic imitation are emanations of the same phenomenon, but detected under different conditions. Similarly to Heyes, they suggested that in both cases imitation is caused by the perception-action link, and that it may also be responsible for other imitative behaviours (see also Chartrand & Bargh, 1999; Dijksterhuis & Bargh, 2001).

Furthermore, recent evidence suggests that the goal to affiliate with others might be another mechanism involved in multiple imitative behaviours. Several studies have shown that the affiliative goal can be extended beyond behavioural mimicry, and that automatic imitation is modulated by social factors that appear to be related to this goal.⁸ Leighton, Bird, Orsini, and Heyes (2010) primed their participants either with a pro-social, neutral or antisocial attitude, and asked them to engage in an automatic imitation task. In this task, participants acted on a cue to open or close their hand while watching a video of an opening or closing hand. The hand movements were initiated faster if the video showed the same than a different movement.

⁸ Note that temporal adaptation may also be affected by various social factors, although in this case the exact casual mechanism is difficult to identify (for reviews, see Hove & Risen, 2009; Keller et al., 2014).

But importantly, the facilitative effect of imitation was stronger in participants primed with a pro-social attitude, as compared to participants primed with either the neutral or anti-social attitude. One interpretation of this finding is that the pro-social priming activated the goal to affiliate with others, which in turn increased the tendency to imitate. Similar results were obtained by Maister and Tsakiris (2016) who showed that automatic imitation is enhanced when interacting with one's romantic partner, as compared to interacting with a friend. This suggests that interaction partners with whom we are more likely to affiliate elicit a stronger automatic imitation effect.

Aragón, Sharer, Bargh, and Pineda (2014) observed this tendency on a neural level: in their study, participants first played an economic game either with a fair partner who shared the resources or an unfair partner who kept the resources for himself. Next, imitative activation of the motor system (indexed by mu rhythm activity) was measured while participants observed the partner perform a simple or a goal-directed hand movement. Participants who interacted with an unfair partner activated their motor system (mu rhythm suppression) only when observing goal-directed actions, whereas participants who interacted with a fair partner showed the activation for both simple and goal-directed actions. Thus, the neural activity related to automatic imitation was modulated by whether prior behaviour of the interaction partner encouraged them to affiliate or not.

Finally, evidence convergent with the idea that automatic imitation is regulated by the affiliative goal comes also from studies exploring the role of individual differences. Obhi, Hogeveen, Giacomin, and Jordan (2014) asked participants to engage in an automatic imitation task, and subsequently to fill out a questionnaire measuring narcissism as a personality dimension. Interestingly, a reduced tendency to imitate was observed in participants scoring high on narcissism, arguably because such individuals might be less motivated to affiliate with others.

To summarise, some recent accounts and findings support the notion that emergent imitation might be caused by multiple mechanisms. Specifically, the perception-action link involved in the simulation mechanism has been suggested to contribute to various imitative behaviours observed both in natural social interactions and in controlled laboratory conditions. Similarly, the unconscious goal to affiliate appears to regulate the automatic tendency to imitate across

simple motor movements and more complex social behaviours. Therefore, it is likely that at least these two mechanisms are capable of explaining imitation beyond the behaviour to which they have been so far confined.

Thus, I argue that psychological research on imitation should be advanced by conducting studies that further explore the possible overlap between the causal mechanisms of emergent imitation. Current candidate mechanisms should not be assumed to be confined to a specific imitative behaviour, unless future experiments will prove otherwise. Instead, studies should test whether each mechanism could be involved in each of the currently known imitative behaviours, i.e. synchrony, emotional contagion, imitative learning, overimitation, mimicry, linguistic imitation, and automatic imitation. This way, better models of imitation could be constructed.

14 AIMS OF THIS THESIS

This thesis contributes to the effort of cross-examining the causal mechanisms of emergent imitation. In the following empirical chapters, I discuss three sets of experiments that aim to investigate whether simulation, temporal adaptation, and the unconscious goal to affiliate could be extended to explain imitative behaviours that are currently underexplored by their respective research fields.

In Chapter 2, I present three experiments that contribute to the exploration of the role of the simulation mechanism in linguistic imitation. Although simulation has been so far considered to be related to imitation of motor movements, a recent account proposed that it might promote imitation also in language (Gambi & Pickering, 2013). However, a critical assumption of the language simulation account remains to be tested, i.e. that in the process of simulation, comprehenders engage their language production system to predict (Pickering & Garrod, 2013). The three experiments presented in this chapter tested this by manipulating the engagement of the production system during comprehension and measuring its effects on prediction.

Chapter 3 explores the possibility that the temporal adaptation mechanism leads to imitation in discrete non-rhythmic motor actions. Studies investigating this mechanism previously focused on rhythmic actions, which led some researchers to assume that it is not involved in

imitation in discrete non-rhythmic actions, and to favour other explanations instead (e.g., Pfister, Dignath, Hommel, & Kunde, 2013). In Chapter 3, I present three further experiments that tested whether spontaneous imitation of partner's response speed that occurs in a joint leader-follower button pressing task can be explained by temporal adaptation. This hypothesis was investigated by manipulating the partner's response speed and the audio-visual cues about partner's responses. The experiments asked whether observing fast responses leads to performing fast responses, and vice versa.

In Chapter 4, I present three additional experiments that investigate if the unconscious goal to affiliate is involved in linguistic imitation. More specifically, if people engage in imitation of language to create affiliation and improve their relation with their conversational partner, then linguistic imitation should have observable positive consequences convergent with the affiliative goal (cf. Lakin, Jefferis, Cheng, & Chartrand, 2003). The experiments tested this prediction by manipulating whether participants were lexically imitated or counter-imitated by their conversational partner, and measuring the effects of imitation, i.e. participants' evaluation of the conversational partner and of the interaction with the partner, and participants' tendency to cooperate with the partner.

Chapter 2

Investigating the Role of Production System in Simulation

Note: This chapter has been modified and submitted for publication as a paper [Lelonkiewicz, J. R., Pickering, M. J., & Rabagliati, H. (under review). The role of language production in making predictions during comprehension.].

1 INTRODUCTION

When reading or listening, people can predict the next word that they will see or hear (e.g., Altmann & Kamide, 1999; DeLong, Urbach, & Kutas, 2005). But what mechanisms do they use to do this? Recently, a number of researchers have proposed that comprehenders predict using aspects of the language production system (*prediction-by-production*: Dell & Chang, 2014; Federmeier, 2007; Pickering & Garrod, 2013; cf. Hickok, 2012). More specifically, comprehenders may covertly imitate the utterance that they are currently perceiving, and use this as the basis for determining what they would say next if they were speaking.

However, the evidence that production is used for prediction is quite indirect. Thus, brain regions that are active during speaking are also active during listening. For instance, motor regions that are implicated in the production of tongue-articulated sounds are also active when comprehenders hear a tongue-articulated, but not a lip-articulated sound (Fadiga, Craighero, Buccino, & Rizzolatti, 2002; Pulvermüller et al., 2006; Watkins & Paus, 2004). However, these findings do not demonstrate that such activation is causally involved in prediction. More importantly, there is some evidence for activation of regions associated when those sounds are predicted (D'Ausilio, Jarmolowska, Busan, Bufalari, & Craighero, 2011). But even this study provides evidence about the prediction of specific sounds, rather than larger units of language such as words. There is some correlational evidence that people with better production skills are also better at predicting language (Federmeier, Kutas, & Schul, 2010; Mani & Huettig,

2012), but these studies do not unambiguously demonstrate a causal role of prediction in production.

The current lack of empirical clarity has led to a number of suggestions as to exactly how prediction-by-production might be used for language processing. Some accounts propose that production is used for generating all predictions (Dell & Chang, 2014), whereas others suggest that it is used especially for predictions that help subsequent production (e.g., responding to a question; Scott, McGettigan, & Eisner, 2009; or engaging in dialogue; Garrod & Pickering, 2015).

In this paper, we report a causal test of prediction-by-production, and investigate the conditions under which it might occur. In our experiments, participants read sentence contexts that either were (1a), or were not (1b), highly predictive of a final word, and we measured how quickly participants recognised that final word (Experiments 1 and 2) or named a picture showing that word (Experiment 3). To increase reliance on top-down prediction, stimuli were presented against a white-noise background and using a text colour that was individually-selected to ensure participants' word recognition was impaired but about chance.

(1a) *It was windy enough to fly a... kite.*

(1b) *They went to see the famous... show.*

Crucially, we also manipulated the engagement of the production system: participants read the contexts aloud on half the trials, and silently on the remainder. We considered reading silently to be representative of normal comprehension where some aspects of production are used by a forward model to generate predictions. But since in reading aloud the production system is highly activated for the purpose of producing speech, the forward model should be more engaged, so any effect of the production system on prediction should be greater in the read-aloud than the read-silently condition. And because the possibility of (accurate) prediction is of course greater for the predictive (1a) than the non-predictive sentences (1b), reading aloud should facilitate comprehension to a greater extent for (1a) than (1b).

Experiment 1 used a lexical decision task: after reading the sentence contexts, participants were instructed to indicate whether the final word was a word or a nonword. An interaction

between predictability and reading type in this experiment would implicate prediction-by-production when the task involves comprehension but not production. Experiment 2 used a go/no-go task in which participants were instructed to read aloud a sentence-final word but not nonword. An interaction would implicate prediction-by-production when the task involves comprehension and some aspects of production. Experiment 3 used a picture naming task, in which participants were instructed to name a sentence-final picture (whose name was a predictable or unpredictable word). An interaction would implicate prediction-by-production when the task involves production but need not involve comprehension.

2 EXPERIMENT 1

2.1 Methods

2.1.1 Participants

Twenty-four participants, who were Edinburgh University students and native speakers of British English, were paid £6. They had normal or corrected-to-normal vision and reported no language disorders.

2.1.2 Design

We used a 2 (Predictability: high- vs low-cloze) X 2 (Reading Type: aloud vs silent) X 2 (Item Type: word vs nonword) within-subjects design. The order of reading aloud/silently was a between-subjects participants manipulation (Reading Type Order: aloud first vs silent first). Prior to the task, we carried out an individual pretest to determine the text colour for the final words.

2.1.3 Materials

In preparation of the stimuli, 24 additional participants produced a final word of 291 different sentences. We selected 120 high-cloze sentences whose final word was highly predictable (produced by 87% of participants) and 120 low-cloze sentences (produced by 20% of participants). High- and low-cloze sentences were matched for number of words ($M_{high} = 7.47$

vs $M_{low} = 7.28$; $t(238) = 1.20$, $p = .232$). We then created a word and a nonword item version of each context sentence by pairing it with either its most-frequent continuation (or selected one in case of a tie), or a pronounceable nonword matched to that continuation in length, first letter, and last letter (Table 1).

Each participant saw 240 items in total. Each context sentence was shown only once, either as a word or nonword item (item type determined randomly for each participant). Trial order was individually randomized.

To ensure participants paid attention, forty trials were followed by a simple yes/no question (e.g., Was it the boat that easily passed under the bridge?). For the text colour pretest, we prepared additional 250 words and 250 nonwords.

Table 1. An example of the stimuli used in Experiment 1.

	context	word / non-word
high-cloze	<i>It was windy enough to fly a</i>	<i>kite / kile</i>
low-cloze	<i>They went to see the famous</i>	<i>show / spow</i>

2.1.4 Procedure

Trials in the text colour pretest started with a central fixation cross displayed against a square of white noise (150 X 150 pixels, black and white; fixation cross shown for 500-1000ms, randomly varied). Then, a single word or a nonword was randomly displayed in one of five colours, anchored on the neutral axis in the RGB colour space and different in lightness level (#414141, #474747, #4D4D4D, #515151, #565656; word/nonword shown for 300ms). Participant pressed a key to signal whether they saw a word or a nonword ('Z' and '/'; key assignment randomized). Each participant saw 250 trials (half words, half nonwords). We identified the text colour at which the participant was closest to 60% accuracy.

Trials in the main experiment began with a central fixation cross, displayed against a square of white noise, surrounded by a white background (1000-1500ms, randomly varied). Sentence contexts were then shown word by word (300ms ON, 200ms OFF), in the same text colour for all participants (#393939). On the blank screen before the final word, the background switched from white to yellow and then the final word was displayed (300ms). Text colour for the final

word was based on the pretest. Participants were instructed to read the words on the white background aloud or silently and then to press a key to indicate whether they thought the yellow screen showed a word or a nonword ('Z' or '/'; key assignment varied across participants). They were told never to read this final word aloud. Trials ended after the participant had responded (Figure 1) or after the question.

The main experiment was divided into two blocks of 120 trials, each of which was preceded by 8 practice trials of the same type (silent or aloud) as the subsequent block. Each experiment lasted about 30 minutes.

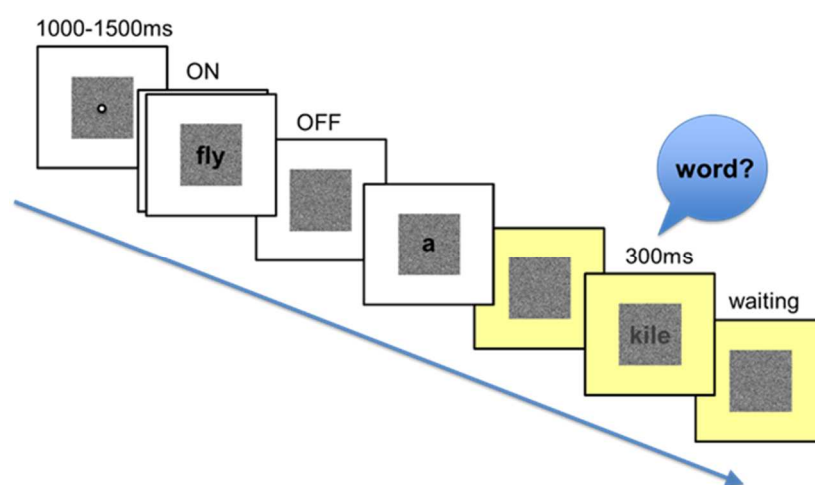


Figure 1. An example of procedure for a trial (nonword item) in Experiment 1.

2.2 Results

To test whether engaging production increased the effect of prediction on lexical decisions, we calculated the likelihood of responding that the final word was an existing word (henceforth: “word” response). We ran a binomial Generalized Linear Mixed Model (GLMM) with Predictability (high vs low), Reading Type (aloud vs silent), Item Type (word vs nonword), and Reading Type Order⁹ (aloud first vs second) as fixed effects, by-subjects

⁹ In the models used in Experiments 1-3, we included Reading Type Order to determine whether there would be any carry-over effects. For example, participants who read aloud first

random intercepts and slopes, and by-items random intercepts. The maximal model structure did not converge, so we removed correlations between random effects, and all three- and four-way interactions between random effects (Barr, Levy, Scheepers, & Tily, 2013; see Appendix A for model description).

If prediction-by-production improves accuracy, the likelihood of correctly making a “word” response (i.e., making a “word” response to a word item) should be higher after reading high- than low-cloze contexts, and this effect should increase when participants read the contexts aloud. Thus, there should be a three-way interaction between Item Type, Predictability, and Reading Type. However, this interaction was not present (Table 3). Alternatively, if prediction-by-production biases participants towards responding the final word is an existing word, there should be a two-way interaction between Predictability and Reading Type, such as the likelihood of making a “word” response should be higher after reading high- than low-cloze contexts and this effect should be enhanced when reading aloud. Crucially, this interaction was also not present.

Instead, we found an effect of Item Type: the likelihood of a “word” response was higher for word than nonword items, reflecting the fact that participants tended to correctly make a “word” response to items that were existing words (Table 2). Moreover, this effect interacted with Predictability: the likelihood of a “word” response was higher for word than nonword items, and this effect was bigger for high- than low-cloze contexts.

could continue to engage their production system in some way also in reading silently (e.g., by imagining hearing themselves read). This could lead to a situation where reading aloud would increase the effect of Predictability, but only for participants who read aloud first. Because of that we could observe a reliable three-way interaction between Predictability, Reading Type, and Reading Type Order, whereas the interaction between Predictability and Reading Type could come out as not reliable. Thus, omitting Reading Type Order in the analyses could potentially result in a Type II error.

Next, we analysed key-press reaction times (RT). For to the analyses, we excluded outliers deviating more than 2.5 SD from each participant's cell mean (2.83%) and retained only the trials where participants gave a correct response to a word item (37.63% of all observations). We then ran a maximal-structure Linear Mixed Effect (LME) model with Predictability, Reading Type, and Reading Type Order as predictors and with by-subject random intercepts and slopes for all the predictors.

If engaging production increases the effect of prediction on key-press RT, there should be an interaction between Predictability and Reading Type. There was an effect of Predictability, such that participants responded faster after high- than low-cloze sentence contexts, and an effect of Reading Type, indicating that participants' responded slower after they had read the context aloud than silently (Table 4). However, again there was no interaction between these effects, suggesting that engaging production did not influence the effects of prediction (Table 5).¹⁰

We also found an additional interaction between Reading Type and Reading Type Order, such that the effect of Reading Type was greater in participants who read aloud in the first block ($M_{aloud} = 1167\text{ms} [\pm 72]$, $M_{silently} = 676\text{ms} [\pm 42]$) than those who read aloud in the second block ($M_{aloud} = 1011\text{ms} [\pm 58]$, $M_{silently} = 853\text{ms} [\pm 51]$; means are henceforth reported with 95% CI). Participants responded correctly to the questions on 90% of trials and there were no differences across conditions (Appendix A).

¹⁰ We replicated these findings when exclusion criteria were not applied (Appendix A).

Table 2. Percentages of “word” responses in Experiments 1 and 2. Table shows mean percentages and 95% CI for each design cell. Note that this table can also be used to calculate the percentages of correct responses: For word items, percentages correct are the same as the percentages currently shown; for nonword items, subtract the values shown in the table from 100%.

Experiment 1				
	word item		nonword item	
	low cloze	high cloze	low cloze	high cloze
reading silently	69% (± 6)	79% (± 5)	28% (± 6)	34% (± 7)
reading aloud	69% (± 6)	82% (± 4)	25% (± 6)	29% (± 7)

Experiment 2				
	word item		nonword item	
	low cloze	high cloze	low cloze	high cloze
reading silently	65% (± 6)	83% (± 6)	26% (± 5)	40% (± 6)
reading aloud	72% (± 6)	82% (± 7)	31% (± 6)	51% (± 8)

Table 3. GLMM analyses of the likelihood of a “word” response in Experiments 1 and 2. Table shows results from the fixed effects structure.

Experiment 1				
	<i>B</i>	<i>SE</i>	<i>z</i>	<i>p</i>
Intercept	.12	.12	1.05	> .250
Predictability	.24	.06	4.14	< .001
Item Type	1.16	.07	15.87	< .001
Reading Type	-.03	.03	-.92	> .250
Reading Type Order	-.07	.12	-.62	> .250
Predictability * Item Type	.10	.04	2.25	.024
Predictability * Reading Type	.02	.04	.46	> .250
Item Type * Reading Type	.08	.04	1.81	.070
Predictability * Reading Type Order	.00	.05	-.09	> .250
Item Type * Reading Type Order	.05	.07	.76	> .250
Reading Type * Reading Type Order	-.04	.04	-1.15	.250

Predictability * Item Type * Reading Type	.03	.03	1.08	> .250
Predictability * Item Type * Reading Type Order	.05	.04	1.44	.150
Predictability * Reading Type * Reading Type Order	-.04	.04	-1.23	.222
Item Type * Reading Type * Reading Type Order	.00	.04	.18	>.250
Predictability * Item Type * Reading Type * Reading Type Order	.00	.03	.08	>.250

Experiment 2

	<i>B</i>	<i>SE</i>	<i>z</i>	<i>p</i>
Intercept	.40	.10	3.83	< .001
Predictability	.46	.04	10.63	< .001
Item Type	1.03	.08	12.39	< .001
Reading Type	.19	.05	3.71	< .001
Reading Type Order	.11	.11	1.12	> .250
Predictability * Item Type	-.03	.05	-.66	> .250
Predictability * Reading Type	.01	.03	.36	> .250
Item Type * Reading Type	-.03	.03	-.94	> .250
Predictability * Reading Type Order	-.03	.03	-1.04	> .250
Item Type * Reading Type Order	.12	.07	1.59	.111
Reading Type * Reading Type Order	.00	.05	-.12	> .250
Predictability * Item Type * Reading Type	-.02	.03	-.77	> .250
Predictability * Item Type * Reading Type Order	-.02	.04	-.67	> .250
Predictability * Reading Type * Reading Type Order	-.02	.03	-.57	> .250
Item Type * Reading Type * Reading Type Order	-.09	.03	-2.89	.004
Predictability * Item Type * Reading Type * Reading Type Order	.04	.03	1.24	.214

Table 4. Participants' RT in Experiments 1, 2, and 3. Table shows means with 95% confidence intervals (ms).

Experiment 1		
	low cloze	high cloze
reading silently	858 (± 52)	679 (± 41)
reading aloud	1209 (± 68)	987 (± 63)
Experiment 2		
	low cloze	high cloze
reading silently	918 (± 29)	868 (± 24)
reading aloud	725 (± 30)	604 (± 33)
Experiment 3		
	low cloze	high cloze
reading silently	598 (± 18)	489 (± 19)
reading aloud	501 (± 22)	320 (± 23)

Table 5. LME analyses of RT in Experiments 1, 2, and 3. Table shows results for the fixed effects structure.

Experiment 1			
	<i>B</i>	<i>SE</i>	<i>t</i>
Intercept	957.70	68.12	14.06
Predictability	207.21	35.30	5.87
Reading Type	-345.16	72.38	-4.77
Reading Type Order	-4.13	135.48	-.03
Predictability * Reading Type	-62.05	55.73	-1.11
Predictability * Reading Type Order	-29.59	64.47	-.46
Reading Type * Reading Type Order	335.38	144.78	2.32
Predictability * Reading Type * Reading Type Order	60.71	111.56	.54
Experiment 2			
	<i>B</i>	<i>SE</i>	<i>t</i>
Intercept	776.68	13.16	59.03
Predictability	86.31	16.57	5.21

Reading Type	230.85	25.06	9.21
Reading Type Order	73.56	26.31	2.80
Predictability * Reading Type	-74.72	29.76	-2.51
Predictability * Reading Type Order	-4.53	33.13	-.14
Reading Type * Reading Type Order	24.63	50.12	.49
Predictability * Reading Type * Reading Type Order	50.04	59.52	.84
Experiment 3			
	<i>B</i>	<i>SE</i>	<i>t</i>
Intercept	487.02	25.27	19.28
Predictability	143.00	27.41	5.22
Reading Type	126.83	19.84	6.39
Reading Type Order	9.88	45.16	.22
Predictability * Reading Type	-70.71	20.97	-3.37
Predictability * Reading Type Order	36.81	30.80	1.19
Reading Type * Reading Type Order	103.42	39.53	2.62
Predictability * Reading Type * Reading Type Order	-40.37	41.63	-.97

3 EXPERIMENT 2

While Experiment 1 showed that participants can predict the final word of a sentence, we found no evidence that production enhanced the aspect of prediction needed for comprehension, as indicated by the lack of an interaction between predictability and reading type.

Experiment 2 investigated whether it enhanced the aspect of prediction needed for production. In a spoken go/no-go task, participants read high- and low-cloze contexts either aloud or silently, and then read aloud the final word if it was a word, but not otherwise. In this experiment, participants' accuracy reflects their ability to comprehend the final word, as in Experiment 1, but the time to articulate the final word reflects the facilitation of their production system. If prediction-by-production helps subsequent production, then participants should take less time to articulate the final word after reading high- than low-cloze contexts, and this boost should increase when they read aloud.

3.1 Methods

3.1.1 Participants

We recruited 32 further participants from the same population and on the same terms as in Experiment 1.

3.1.2 Materials, Procedure, and Design

The experiment was identical to Experiment 1, except that participants were instructed to read the final word out loud if it was a word and not read it otherwise. Responses were recorded for 3000ms from the onset of the final word, using a microphone positioned in front of the participant.

3.2 Results

Two trained coders analysed the recordings from the experiment. They identified the trials when participants read out the final word and calculated participants' RT on these trials (i.e., time from recording onset until participants started reading the final word). The inter-rater reliability between coders for RT (two-way random, consistency ICC = .99; calculated on 6.25% data) was in the excellent range (Cicchetti, 1994).

To test whether prediction-by-production affects comprehension, we calculated the likelihood of a "word" response (i.e., reading the final word aloud) using a binomial GLMM with Predictability, Reading Type, Item Type, and Reading Type Order as fixed effects, by-subjects random intercepts and slopes, and by-items random intercepts. We removed correlations between random effects to help convergence (see Appendix A for model description).

We replicated the results of Experiment 1: engaging the production system did not increase the effect of prediction on participants' spoken lexical decisions. As before, there was an effect of Predictability, reflecting the fact that participants more often made a "word" response after high-cloze contexts, and an effect of Item Type, indicating that participants more often made a "word" response to a word than a nonword item (Table 2). However, as in Experiment 1,

there was no interaction between Predictability and Reading Type, and no further interactions involving both of these predictors (Table 3).

We also found an additional effect of Reading Type, such that participants more often made a “word” response after they had read the context sentence aloud than silently, most likely due to the fact that after reading the contexts aloud it was easier to carry on and read the final word aloud as well, rather than inhibit speech. Moreover, there was a three-way interaction of Reading Type Order with Reading Type and Item Type, reflecting the fact that participants who read aloud in the first block made a “word” response to a word item slightly less often after reading aloud than silently (17% [± 2] vs 18% [± 1]), but the opposite was true for participants who read aloud in the second block silently (17% [± 1] vs 16% [± 1]).

To test whether prediction-by-production facilitates subsequent production, we analysed participants’ RT on trials where they read aloud the final word (58.13% of the full dataset). Prior to the analyses, we excluded outliers (.58% of trials where they read the final word) and error trials (i.e., trials where participants read the final word when in fact it was a nonword; further 33.60%). Moreover, we removed trials where in reading aloud participants were still reading the context after the onset of the final word (further 17.82%). We then ran a maximal-structure LME model with Predictability, Reading Type and Reading Type Order as fixed effects, by-subjects random intercepts and slopes, and by-items random intercepts.

Unsurprisingly, we found effects of Predictability and Reading Type: participants were faster to read the final word after a high-cloze context, and were also faster after they had read the context aloud (Table 4). Crucially, however, we found an interaction between these factors: the effect of Predictability on reaction times was greater when participants had read the sentence contexts aloud (Table 5). That is to say, the effect of prediction on response time was greater when using production.¹¹

¹¹ This interaction was also present when exclusion criteria were not applied (Appendix A).

Participants correctly responded to the questions on 85% of trials. Participants were slightly more likely to produce a correct response in reading aloud, but the effect of Reading Type did not interact with Predictability (Appendix A).

4 EXPERIMENT 3

Experiment 2 found that prediction-by-production affected production in a spoken lexical decision task. Predictive contexts facilitated participants' utterances to greater extent if participants had read those contexts aloud than otherwise. Experiment 3 aimed to replicate this finding in a task that involved the production system, but not lexical judgment. We employed a picture naming task that has been previously used to investigate facilitation of the production system (cf. Drake & Corley, 2015): participants read high- or low-cloze contexts either aloud or silently, and named a picture that appeared as an illustration of the final word. If prediction-by-production facilitates subsequent production, then participants' response times should be more affected by prediction if they had read the contexts aloud.

4.1 Methods

4.1.1 Participants

We recruited 32 further participants from the same population and on the same terms.

4.1.2 Design



In Experiment 3, we employed a 2 (Predictability: high- vs low-cloze) X 2 (Reading Type: aloud vs silently) within-subjects design. Participants read high- and low-cloze sentence contexts, half of the time aloud, and half of the time silently (Reading Type Order was counter-balanced between participants). The sentence contexts were followed by a picture and participants were asked to name it out loud to a microphone.

4.1.3 Materials

Stimuli were 60 high-cloze and 60 low-cloze sentence contexts (length-matched: $M_{high} = 8.10$ vs $M_{low} = 7.83$; $t(118) = -1.17$, $p = .244$), each paired with a picture.¹² Cloze values were determined by 24 additional participants, who guessed the final word of 206 different sentences. The most frequent continuation was used, on average, by 92% of participants for high-cloze contexts, and 16% for low-cloze contexts. Each high-cloze context was paired with a picture showing its most frequent continuation, and each low-cloze context with a picture showing a possible, but not the most frequent continuation (Table 6). Pictures were nameable with a single word, had high name agreement ($M = .89$) and high name frequency ($M = 4.16$).

Each participant saw two lists each comprising 30 high- and 30 low-cloze items. Lists were matched for context length ($M = 8.08$ vs $M = 7.85$; $t(118) = 1.02$, $p > .250$), picture name agreement ($M = .86$ vs $M = .91$; $t(113) = -1.62$, $p = .108$), name frequency ($M = 4.20$ vs $M = 4.12$; $t(117) = .88$, $p > .250$), and name length in syllables ($M = 1.53$ vs $M = 1.73$; $t(111) = -1.39$, $p = .165$). Item order was randomized within each list for each participant. The order of lists was counterbalanced between-participants. Twelve items were followed with a question. Pictures and norms for picture name agreement were taken from the Bank of Standardized Stimuli (BOSS v.2; Brodeur, Guérard, & Bouras, 2014). Norms for picture name frequency and length were taken from SUBTLEX-UK (Van Heuven, Mandera, Keuleers, & Brysbaert, 2014)

Table 6. An example of the stimuli used in Experiment 3.

	context	picture
high-cloze	<i>It was windy enough to fly a</i>	
low-cloze	<i>They went to see the famous</i>	

¹² These contexts were different than in Experiments 1-2.

4.1.4 Procedure

Trials began with a fixation cross, followed by a sentence context presented as in Experiments 1-2. Each context was followed by a picture and participants were instructed to name it with a single word, as fast as possible. Responses were recorded for 3000ms from picture onset by a microphone positioned in front of the participant. Trials ended after the timeout of the recording (Figure 2) or the question response.

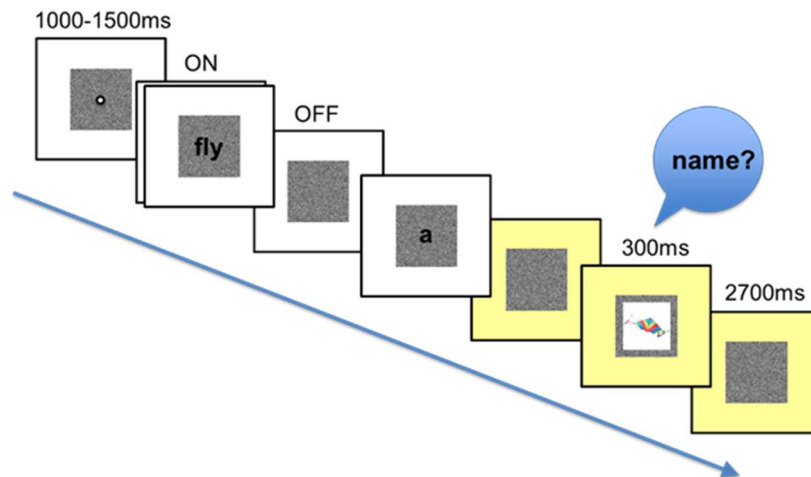


Figure 2. An example of a trial in Experiment 3.

4.2 Results

Three trained coders calculated participants' RT (i.e. time from picture onset until naming onset). The inter-rater reliability was excellent (two-way random, consistency ICC = .99; calculated on 6.25% data). Prior to the analyses we removed outliers (3.31%), and trials where in reading aloud participants were still reading the sentence context after the onset of the picture (16.30%). As a result of this, two participants lost most observations in some design cells. We excluded their data from further analyses.

To test whether reading the context aloud enhanced the facilitative effect of prediction, we ran a maximal-structure LME model with Predictability, Reading Type, and Reading Type Order as fixed effects, by-subjects random intercepts and slopes, and by-items intercepts. We successfully replicated the key finding of Experiment 2, an interaction between Predictability

and Reading Type (Table 5). Participants named the pictures faster after high-cloze sentence contexts, and this effect was larger if they had read the contexts aloud (Table 4).¹³

There was also an additional interaction between Reading Type and Reading Type Order, such that the effect of reading aloud was greater in participants who read aloud in the second ($M_{aloud} = 397\text{ms} [\pm 24]$, $M_{silently} = 571\text{ms} [\pm 21]$) than those who read aloud in the first block ($M_{aloud} = 425\text{ms} [\pm 23]$, $M_{silently} = 516\text{ms} [\pm 16]$). However, this did not further interact with predictability. There were no other effects or interactions.

As in Experiments 1-2, participants almost always responded correctly to the questions (84%). However, they gave more correct answers after high- than low-cloze contexts (Appendix A).

5 GENERAL DISCUSSION

Across three experiments, we found evidence that engaging the production system during comprehension increases the effects of linguistic prediction. In tasks that involved speaking the final word of a sentence (Experiments 2-3), participants spoke sooner if they had read a high- than low-cloze sentence, indicating that highly constraining contexts allowed for stronger predictions about the sentence-final word. Crucially, this effect was enhanced when participants had read the sentence aloud than silently. This suggests that engaging production during comprehension helps to predict the next upcoming word in the sentence, and that such predictions are useful for subsequent spoken production. However, we did not find evidence that predictions generated by the production system aid comprehension, at least when comprehension is indexed by lexical decision. In tasks that involved lexical decision (Experiments 1-2), participants more often responded that the final word was an existing English word after reading high- than low-cloze contexts, but this tendency was not affected by the engagement of production.

¹³ We obtained the same pattern of results when exclusion criteria were not applied (Appendix A).

We now interpret our findings in relation to Pickering and Garrod's (2013) account, and then discuss how they might accommodate the differences between Experiment 1 and 2-3. Pickering and Garrod (PG) argued that comprehenders use a particular form of prediction-by-production that they call prediction-by-simulation, which is derived from processes involved in language production. When people produce utterances, they learn the relationship between their intention (or production command) and linguistic (and non-linguistic) properties of the utterance, such as the sounds of the words that they utter. Over time, they can learn to predict aspects of their experience of producing an utterance, as soon as they have the intention to produce that utterance, using so-called forward models. For example, they might develop the intention to say kite, and then rapidly predict that they will experience themselves saying /kaIt/ (or perhaps just the initial /k/). When they hear someone else speaking, they covertly imitate that person and (making allowances for differences between that person and themselves) use their forward models to predict their upcoming experience of what the speaker will say next. So if they covertly imitate someone saying It was windy enough to fly a ..., they would then predict the experience of hearing /kaIt/ (or /k/).

Any prediction of /kaIt/ will facilitate comprehension or production of that word. Thus our evidence that comprehension and production is facilitated in high-cloze contexts is compatible with prediction. But our finding that prediction is enhanced by production provides support for PG account. Specifically, reading aloud turns covert imitation into overt imitation – participants now engage the production system directly, as well as the comprehension system, and therefore facilitate the construction of forward models associated with the context.

PG's account, however, does not explicitly suggest that prediction-by-production should affect production but not comprehension. But of course producing the target word (whether in reading it aloud or naming a picture) leads to further activation of the production system, and does so while the participant is preparing the act of production – in other words, when prediction is likely to be effective. Put another way, production of the sentential context activates the forward model under all circumstances, but the forward model is more effective in shaping the upcoming act of production rather than the act of comprehension. This is compatible, for example, with Drake and Corley's (2015) finding (using ultrasound

recordings) that production of a target word is affected by articulatory movements associated with a different highly predicted word.

We found no evidence of prediction-by-production when the target word was merely comprehended (Experiment 1). This did not accord with our hypotheses, and there are two possible explanations. One is that the lexical decision task does not sufficiently engage with prediction-by-production, perhaps because its focus is on form acceptability rather than meaning. Alternatively, prediction-by-production may only be used or used strongly when the comprehender is about to speak. This would accord with the possibility that activation of the production system during comprehension is partly used to help their subsequent production (Scott et al., 2009; Garrod & Pickering, 2015). And it would imply that prediction-by-production would be particularly effective in dialogue – something which is probably necessary given the problem that interlocutors face in taking turns with delays that are regularly shorter than the time it takes to prepare even a single word (see Levinson, 2016).

Finally, we made our task difficult by making the context somewhat hard to read. By doing so, we required more top-down processing than might be required under clear conditions. Assuming that such top-down processing makes use of the production system, the use of adverse conditions might have enhanced any effects. Future work could determine if this is the case by manipulating the extent of contextual difficulty.

Chapter 3

Investigating the Role of Automatic Temporal Adaptation in Imitation

Note: This chapter has been published as a paper in *Psychonomic Bulletin & Review* [Lelonkiewicz, J. R., & Gambi, C. (in press). Spontaneous adaptation explains why people act faster when being imitated. *Psychonomic Bulletin & Review*. doi:10.3758/s13423-016-1141-3].

1 ABSTRACT

The human ability to perform joint actions is often attributed to high-level cognitive processes. For example, the finding that action leaders act faster when imitated by their partners is interpreted as evidence for anticipation of other's actions [Pfister, R., Dignath, D., Hommel, B., & Kunde, W. (2013). It takes two to imitate: anticipation and imitation in social interaction. *Psychological Science*, 24, 2117–2121.]. In two experiments, we showed that a low-level mechanism can account for this finding. Action leaders were faster when imitated than counter-imitated, but only if they could observe their partners' actions (Experiment 1). Crucially, when due to our manipulation partner's imitative actions became slower than counter-imitative actions, leaders also became slower when imitated and faster when counter-imitated (Experiment 2). Our results suggest that spontaneous temporal adaptation is a key mechanism in joint action tasks. We argue for a reconsideration of other phenomena traditionally attributed solely to high-level processes.

2 INTRODUCTION

When people engage in a joint activity, they tend to closely coordinate their actions. For example, a couple enjoying a night stroll on the beach might walk in synchrony, holding hands and jointly navigating to avoid puddles of water. This could be viewed as a case of planned

coordination – one that results from shared representations of the desired outcome and the actions necessary to achieve it. However, coordination can also emerge spontaneously, independent of complex representations and high-level cognitive processes (Knoblich, Butterfill, & Sebanz, 2011). For example, the couple on the beach might coordinate their footsteps as a result of low-level automatic mechanisms present in both agents. In this paper, we focus on one such mechanism, i.e. temporal adaptation. We propose that spontaneous temporal adaptation can account for some findings that have previously been taken as evidence that agents represent and anticipate each other's actions.

A great deal of research supports the notion that agents successfully coordinate their actions via high-level processes. For instance, people acting together form and pursue joint goals (Loehr & Vesper, 2016), are aware of each other's focus of attention (Böckler, Knoblich, & Sebanz, 2012), mentalize about their co-actors' perspective (Ryskin, Benjamin, Tullis, & Brown-Schmidt, 2015) and beliefs (van der Wel, Sebanz, & Knoblich, 2014), and form precise representations of each other's actions (Sebanz, Bekkering, & Knoblich, 2006) and their anticipated outcomes (Pfister, Dolk, Prinz, & Kunde, 2014).

However, there is also clear evidence that people coordinate by engaging simpler mechanisms. Temporal adaptation is a low-level mechanism that is particularly important for interpersonal coordination (Konvalinka, Vuust, Roepstorff, & Frith, 2010) and has been shown to often occur automatically (Keller, 2008; Mills, van der Steen, Schultz, & Keller, 2015). Many forms of human interaction are shaped by the tendency to adapt to each other's actions. For example, musicians playing a duet adjust their subsequent performance to correct for asynchronies (Goebel & Palmer, 2009), audiences fall into one clapping rhythm (Neda, Ravasz, Brechte, Vicsek, & Barabasi, 2000), interlocutors align on patterns of body sway (Fowler, Richardson, Marsh, & Shockley, 2008), and people rocking in rocking chairs spontaneously synchronize the frequencies of their movements (Richardson, Marsh, Isenhower, Goodman, & Schmidt, 2007).

We believe that adopting a more low-level perspective can inform the efforts to create a comprehensive framework of joint action. Importantly, it can help to address the criticisms that have been moved against some of the high-level accounts. For instance, mental inferences (Shintel & Keysar, 2009) and anticipation (Pfister, Pfeuffer, & Kunde, 2014) are time-

consuming and effortful in terms of cognitive resources, suggesting their widespread use is unlikely. Furthermore, it has been argued that some aspects of joint action (e.g., synchronization in time) are best explained via low-level mechanisms rather than via common coding and other representational theories (Schmidt, Fitzpatrick, Caron, & Mergeche, 2011). Most importantly, recent studies suggest that phenomena that have traditionally been interpreted in terms of complex high-level processes can in fact be explained by much simpler mechanisms (see Dolk et al., 2014 for review). Here we show that the apparent effect of anticipation of a co-actor's action on one's own action is one such phenomenon.

Anticipation has been advanced as key for successful coordination between agents (Knoblich & Jordan, 2003; Kourtis, Sebanz, & Knoblich, 2013). It has been suggested that anticipating the sensory consequences of one's own action can activate the motor programme that normally produces this action (Hommel, Müsseler, Aschersleben, & Prinz, 2001; Hommel, 2013). For example, in one classic study the button presses of a participant were followed by a light effect whose location was either compatible or incompatible with the location of the presses. Actions were initiated faster in the compatible effect condition, suggesting that participants anticipated the location of the effect and used it as a cue to activate the motor programme for a spatially-corresponding press (Kunde, 2001). In joint action, anticipating the partner's response could cue the agent to activate the action that typically causes this response (Müller, 2015; Pfister, Dolk, Prinz, & Kunde, 2014). Such anticipation could prime the execution of complementary movements, ultimately benefiting any activity that requires two people to coordinate their actions.

One striking demonstration of this process comes from a recent study by Pfister, Dignath, Hommel and Kunde (2013). In this study, one participant acted as a leader and performed a short or long button press in response to a cue on the computer screen. Her partner acted as a follower and was instructed to perform either the same (imitation) or the opposite type of press (counter-imitation). The study found that the leader initiated her actions faster when she was imitated. The authors interpreted this as evidence for anticipation of the follower's movements, in line with the literature on compatibility effects and the ideomotor theory (Hommel et al., 2001). However, follower's actions were not just compatible in the imitation condition and incompatible in the counter-imitation condition. The authors also report that the follower was

faster in the former than the latter condition. In fact, there is a large body of research showing that action execution is facilitated for imitative movements (see Heyes, 2011 for review).

We propose that a much simpler temporal adaptation mechanism can account for this finding: The leader adapted her response speed to the follower's, i.e., speeding up when her partner performed the faster imitative movements and slowing down when he performed the slower counter-imitative movements. Although most of the evidence for temporal adaptation comes from research on rhythmic, continuous movements (e.g., Repp, 2005; Repp & Su, 2013), some studies suggest it can also occur in non-rhythmic, discrete tasks (Jung, Holländer, Müller, & Prinz, 2011). We hypothesised temporal adaptation may play a key role in our task, although this task has been previously used to investigate high-level processes.

We investigated this hypothesis in two experiments. In Experiment 1, we cancelled out visual and auditory feedback about the followers' performance. We hypothesised that if the effect in leaders' response times (RT) is due to temporal adaptation, then it should disappear after removing the perceptual information about the follower's behaviour. In Experiment 2, we manipulated followers' responses to elicit a reversed RT pattern, i.e., faster in counter-imitation, slower in imitation. If leaders accommodate their response speed to this atypical pattern this would be strong evidence in favour of the adaptation hypothesis.

3 EXPERIMENT 1

3.1 Methods

We invited 24 previously unacquainted participants (20 female, 4 male; all right-handed) to form same-gender pairs. This sample size was chosen based on Pfister et al. (2013). Participants were Edinburgh University students with no reported motor disorders and were paid £6 for their time. The study was approved by the Psychology Research Ethics Committee at Edinburgh University and informed consent was obtained from all participants.

Participants were randomly assigned the roles of leader and follower and seated across a table. In each trial, the leader watched the computer screen change colour from black to either red or green, indicating a short (1-150 ms) or long response (200-600 ms). Colour-response mapping was counter-balanced between pairs. The follower was instructed to observe the leader's

action and perform the same (compatible; imitation condition) or the opposite type of button press (incompatible; counter-imitation condition). After the follower's response the screen turned black for 1000 ms and then the next trial started. The participants were instructed to perform their action as quickly as possible. The total duration of a trial was 4000 ms: initial black screen (500 ms) + colour cue (2500 ms) + end trial black screen (1000 ms).

There were 14 practice trials at the beginning of each session to familiarise participants with the two press types. After practice, participants completed one imitation and one counter-imitation block. Then they switched roles and completed two more blocks, so that each person completed the task both as leader and as follower. Each block consisted of 120 trials and the order of blocks was counter-balanced between pairs.

In order to remove visual and auditory feedback about the follower's performance, we placed a divider between participants. This set up allowed the follower to see the leader's hand and the button box, while the leader could not see the follower at all (Figure 3). Furthermore, the leader wore earplugs, as well as noise cancelling headphones (Sony MDR-NC60). To make sure that participants knew what type of response would be performed by their partner in each condition, instructions were carefully explained to them at the beginning of the session and then repeated before the start of each block (i.e., leaders were told the colour-response mapping, informed whether it was an imitation or counter-imitation block, and explained how the follower would respond to their actions). At the end of the session, participants were paid and debriefed.

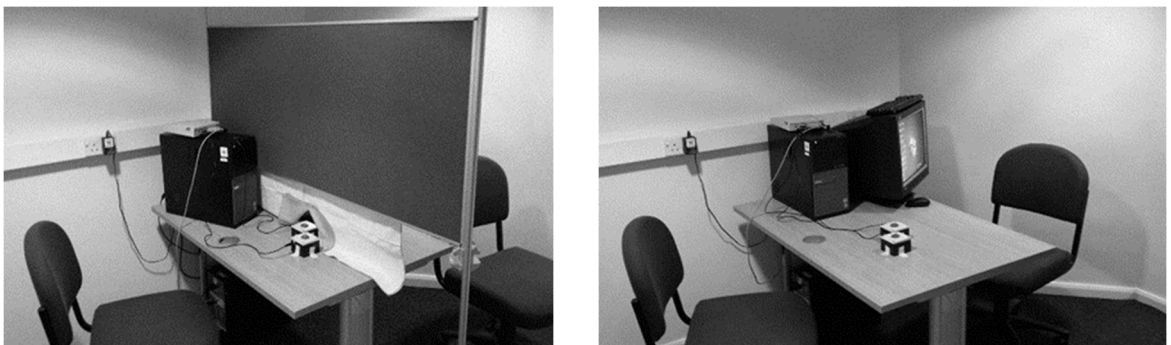


Figure 3. The set-up of Experiments 1 and 2. The photograph on the left shows Experiment 1: The leader is seated on the right-hand side of the divider. The diagonal positioning of the button boxes allows the follower to see both his and the leader's hands, while the leader can

see only her own hand. The photograph on the right shows Experiment 2: The participants can freely observe each other.

3.2 Results

Following Pfister et al. (2013), we discarded the first 24 trials from each block (warm-up trials). Prior to the analyses of the leader's responses, we excluded all trials where the leader performed the wrong type of press (3.03%). We also excluded outliers deviating more than 2.5 SD from each participant's condition mean (2.02%). For the follower's analyses, we excluded trials where either participant made an error (8.87%) and further trimmed the data removing follower's outliers (1.91%)¹⁴. Below we focus on the effect of imitation vs. counter-imitation overall, and separately for each type of leader's press; see Appendix B for full ANOVA results.

We replicated the well-established imitation facilitation effect: Followers' RT were shorter in the imitation than in the counter-imitation condition ($M = 318$ ms vs $M = 459$ ms; $t(23) = 5.79$, $p < .001$, 95% CI = [92, 195]; all reported t-tests are two-tailed). To check whether this effect was independent of leaders' response type, we ran follow-up pairwise comparisons for short and long leader presses (all subsequent analyses refer to leader's press type). There was a significant difference (Bonferroni: $p = .025$) between the imitation and counter-imitation condition for both long ($M = 308$ ms vs $M = 392$ ms; $t(23) = 2.82$, $p = .010$, $r = .51$, 95% CI = [24, 154]) and short presses ($M = 328$ ms vs $M = 526$ ms; $t(23) = 7.64$, $p < .001$, $r = .85$, 95% CI = [148, 258]). This shows that in imitation followers initiated their actions faster, regardless of the type of response performed by the leaders.

Importantly, however, leaders were not faster when they were imitated than when they were counter-imitated, suggesting that removing perceptual feedback considerably attenuated any influence of partner's performance ($M = 434$ ms vs $M = 441$ ms; $t(23) = 1.20$, $p = .241$, $r =$

¹⁴ Outlier rejection did not affect the results in any of the analyses reported in this paper: The same pattern of results was obtained when outliers were retained (see Appendix B).

.24, 95% CI = [-5, 19]) (Figure 4). Follow-up pairwise comparisons showed there was no difference between imitation and counter-imitation for long presses ($M = 444$ ms vs $M = 443$ ms; $t(23) = -.15$, $p > .250$, $r = .03$, 95% CI = [-16, 13]). For short presses, the p-value for the condition effect was just below the conventional alpha threshold, but not below the threshold corrected for multiple comparisons ($M = 425$ ms vs $M = 440$ ms; $t(23) = 2.10$, $p = .047$, $r = .40$, 95% CI = [0, 29]; Bonferroni: $p = .025$).

3.3 Discussion

Our results suggest that the effect on leaders' RT reported by Pfister et al. (2013) is not due to anticipation. If it were, then we should have observed a reliable difference between the conditions even when leaders were unable to observe followers' actions. There is evidence that co-actors seated in separate rooms can represent each other's actions (Atmaca, Sebanz, & Knoblich, 2011; Gambi, Van de Cavey, & Pickering, 2015). Therefore, a strong version of the anticipation account would predict that merely knowing whether the partner will respond with a compatible or an incompatible action should influence leader's action execution (Pfister, Pfeuffer, & Kunde, 2014).

However, it is possible that by cancelling perceptual feedback we made it impossible for the leader to represent the follower's response as a consequence of their action. Under a weaker version of the anticipation account, leaders integrate the followers' actions into representations of the outcomes of their own actions only if they can directly observe the followers. Therefore, in Experiment 2 we reintroduced feedback and manipulated followers' response speed so that they initiated their button presses faster in counter-imitation than in imitation. If the weak version of the anticipation account is correct, we would expect leaders to still show an imitation facilitation effect. But if leaders simply adapt to the speed with which followers respond, they should now be faster in counter-imitation than in imitation.

4 EXPERIMENT 2

4.1 Methods

We recruited 48 further previously unacquainted participants (36 female, 12 male; all right-handed with no motor disorders; participants formed same-gender pairs). Participants were Edinburgh University students and were paid £6. An additional pair of participants was tested, but excluded from the study prior to data analysis (one participant from that pair reported to be left-handed after completing the task). Ethical approval and participants' consent were obtained as in Experiment 1.

We used the same set up and stimuli as in Experiment 1, although this time participants could see and hear each other, i.e., there was no divider and the leader did not wear earplugs or headphones (Figure 3). As previously, we asked followers to observe the leaders and produce either the same (imitation) or the opposite (counter-imitation) type of press. In addition, followers were now asked to wear headphones (Sony MDR-NC60) and explained that they would hear some auditory cues. In the imitation block, followers heard a single tone “GO signal” (160 ms, 800 Hz), played 800-1075 ms after the onset of the trial. They were instructed to withhold their response until they had heard the tone. In counter-imitation, followers heard either a short (80 ms) or a long single tone (240 ms, 800 Hz), played at trial onset. We told them that the short tone indicated they would need to perform a short press, and conversely the long tone indicated a long press. The followers were instructed to use these cues to prepare their response to the upcoming leader's action.

The instructions were given to the follower separately so that the leader was unaware of the purpose of the auditory cues. However, each participant acted in both roles throughout the experiment. Half of the participants started as a leader and then swapped roles to perform the task again as a follower. Hence, they were unaware of the auditory cue instructions while acting as a leader. The other half of participants started as a follower and then carried on to be a leader. This group was therefore aware of the follower's instructions while acting as a leader. To accommodate for this new between-participants factor, we increased the sample size as specified above. Leaders received identical instructions to Experiment 1.

4.2 Results

Similarly to Experiment 1, warm-up trials, error trials (3.59%) and outliers (2.13%) were removed prior to analysing the leader's responses. Error trials for both participants (18.04%), as well as further outliers (1.33%) were excluded for the follower's analyses.

With regards to the follower's behaviour, we successfully reversed the typical RT pattern (Figure 4). Followers were now significantly slower in the imitation than in the counter-imitation condition ($M = 654$ ms vs $M = 298$ ms; $t(47) = -16.23$, $p < .001$, $r = .92$, 95% CI = [-402, -314]), and pairwise comparisons showed this was the case for both long ($M = 533$ ms vs $M = 286$ ms; $t(47) = -10.45$, $p < .001$, $r = .84$, 95% CI = [-302, -204]) and short leader presses ($M = 781$ ms vs $M = 310$ ms; $t(47) = -21.06$, $p < .001$, $r = .95$, 95% CI = [-512, -423]). See Appendix B for full ANOVA results.

Crucially, we observed the same pattern in leader's RT: Leaders were significantly slower in imitation than counter-imitation ($M = 470$ ms vs $M = 450$ ms; $t(47) = -3.06$, $p = .004$, $r = .41$, 95% CI = [-31, -6]) (Figure 4). Again, this difference was significant both for long ($M = 481$ ms vs $M = 462$ ms; $t(47) = -2.78$, $p = .008$, $r = .38$, 95% CI = [-31, -5]) and short presses ($M = 459$ ms vs $M = 439$ ms; $t(47) = -2.87$, $p = .006$, $r = .39$, 95% CI = [-33, -6]). Furthermore, it was not affected by whether leaders were aware of the followers' instructions. A 2 (Condition: imitation vs counter-imitation) X 2 (Leader Press Type: short vs long) X 2 (Leader Awareness: aware vs unaware) mixed ANOVA found that the interaction between Condition and Leader Awareness was not significant ($F(1,46) = 2.90$, $p = .095$, $\eta_G^2 < .01$). All other interactions were also non-significant (F 's < 1).

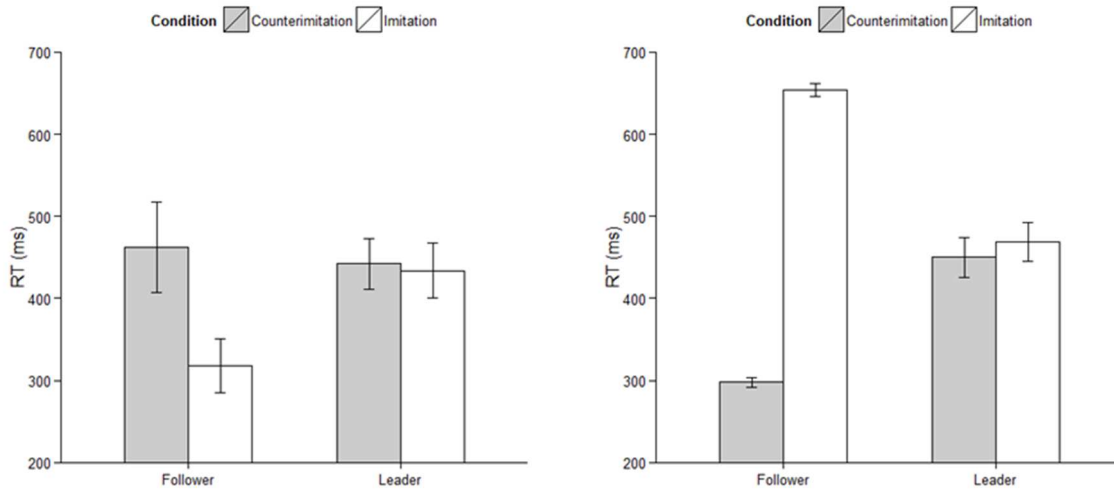


Figure 4. Mean leaders' and followers' response times (RTs) in imitation and counterimitation. Error bars represent 95 % confidence intervals. The graph on the left shows results from Experiment 1, the graph on the right results from Experiment 2.

These results may indicate that leaders adapted their response speed to their partners'. To further test this, we calculated the mean difference between the imitation and the counter-imitation condition for each participant acting as follower and leader and then correlated these differences within participant pairs. There was a positive correlation between the difference in the follower and in the leader within the same pair ($r(48) = .36$, $p = .011$), suggesting that leaders showed larger differences between conditions when their partners did too. Further corroborating our predictions, we found a similar correlation in a separate experiment which was a direct replication of Pfister et al. (2013) ($r(24) = .53$, $p = .008$; see Appendix B for details about the replication experiment). Interestingly, such correlation was not significant in Experiment 1, where leaders could not see the followers ($r(24) = .04$, $p > .250$).

Moreover, we investigated whether the leader's RT on the current trial could be predicted by her partner's RT on the preceding trial. We ran a Linear Mixed-Effect model with by-participants random intercepts and slopes, and with no correlations between the random effects (the maximal structure model did not converge). We specified the follower's RT on the preceding trial as a predictor of leader's RT on the current trial, and found that the leader's action was faster, the faster her partner's action on the preceding trial ($B = 4.60$, $t = 2.65$). This effect was qualified by a significant interaction with condition ($B = -8.50$, $t = -2.53$; Figure S2, panel b). In counter-imitation, there was a positive relationship ($B = 8.91$, $t = 3.23$) indicating local adaptation. In imitation, however, there was no significant association ($B = .14$, $t = .07$),

most likely because followers acted in response to a randomly-timed GO-signal, which rendered adaptation not possible. Finally, a significant association between follower's RT on previous trial and leader's RT on the current trial was also present in our replication of Pfister et al. (2013) ($B = 7.91$, $t = 2.14$; Figure S2, panel c). To the contrary, there was no such association in Experiment 1, indicating that local temporal adaptation was not possible without perceptual feedback ($B = -1.38$, $t = -.68$; Figure S2, panel a).¹⁵

5 GENERAL DISCUSSION

Taken together, our findings demonstrate that spontaneous adaptation of response speed, and not high-level anticipation of partners' actions, is the key mechanism at play in this task. The response facilitation in leaders (Pfister et al., 2013) disappeared once we removed auditory and visual information about their partners' behaviour, suggesting that perceptual feedback was necessary for the emergence of this effect (Experiment 1). Crucially, we showed that the effect in leaders can be reversed by manipulating the followers' RT pattern (Experiment 2). When followers responded faster in counter-imitation than in imitation, leaders were also faster in the former than in the latter condition. This occurred despite the fact that followers' responses were still incompatible in counter-imitation and compatible in imitation.

Therefore, our results are not consistent with the high-level anticipation account. Leaders' behaviour was influenced by the temporal features of the followers' responses and we found no evidence that leaders formed abstract representations of their partners' actions (i.e., represented those actions as being short or long). We propose that our findings are better explained by a low-level mechanism of spontaneous temporal adaptation. In support of this, the magnitude of the condition difference for the leader was correlated with the magnitude of the condition difference for the follower in the same pair only if they could observe each other

¹⁵ We found a corresponding pattern of results in an additional cross-correlation analysis: leader's RT on the current trial was positively correlated with follower's RT on the previous trial in Experiment 2 and in the Replication experiment, but not in Experiment 1 (see Appendix B).

(i.e., in Experiment 2 and our replication of Pfister et al., but not in Experiment 1). This is in line with previous studies, showing that temporal adaptation is contingent on perceptual information uptake (Richardson, Marsh, & Schmidt, 2005; Nowicki, Prinz, Grosjean, Repp, & Keller, 2013). Moreover, when leaders could observe followers, leaders' RT on the current trial was predicted by the followers' RT on the preceding trial. This indicates that the adaptation occurred locally, on trial-by-trial basis. Similarly, a recent study found that dyads engaged in a joint tapping task showed mutual temporal adaptation on a tap-to-tap basis (Konvalinka et al., 2010).

In light of our findings, we argue for a reconsideration of other phenomena traditionally explained by appealing solely to high-level processes. There is already evidence that agents do not form representations of their partner's actions when the partner is outside their peripersonal space (Guagnano, Rusconi, & Umiltà, 2010), which is consistent with an important role for perceptual feedback. More importantly, apparent evidence for action co-representation (Sebanz, Knoblich, & Prinz, 2003) can be obtained when the partner is inactive or replaced with an attention-grabbing object (Dolk, Hommel, Prinz, & Liepelt, 2013). Recent, more parsimonious accounts of joint action posit that agents do not always need to represent and anticipate each other's actions (Vesper, Butterfill, Knoblich, & Sebanz, 2010; Wenke et al., 2011). We suggest that low-level mechanisms like temporal adaptation should be considered whenever investigating human coordination (cf. Richardson, Campbell, & Schmidt, 2009; Vesper & Richardson, 2014).

Finally, it is important to note that we do not argue that anticipation plays no role in joint action. Agents flexibly switch between different coordination processes given the task constraints (e.g., Skewes, Skewes, Michael, & Konvalinka, 2015; Vesper, Schmitz, Safra, Sebanz, & Knoblich, 2016), and so anticipation of co-actor's actions may be involved in some instances of coordination. Moreover, recent accounts of rhythmic joint action suggest that agents anticipate temporal features of their co-actor's action and that coordination depends both on temporal anticipation and adaptation (Keller et al., 2014; Konvalinka et al., 2010; van der Steen & Keller, 2013). Future research should aim to uncover the relationship between anticipation and adaptation, and further investigate the role of task structure in eliciting different coordination mechanisms. Our results show it is essential that researchers consider

both the high- and low-level perspective when building and testing theoretical frameworks of joint action. Only then will these models offer robust explanations and reflect the rich interplay between different mechanisms shaping human coordination.

Chapter 4

Investigating the Social Consequences of Linguistic Imitation

Note: This chapter has been modified and submitted for publication as a paper [Lelonkiewicz, J. R., Pickering, M. J., & Branigan, H. P. (under review). The benefits of being a conversational chameleon: Lexical imitation boosts evaluation of an interaction and encourages cooperation.].

1 ABSTRACT

When in conversation, people imitate various characteristics of each other's language, including the choice of words. This fascinating phenomenon has been explained by appealing to automatic priming mechanisms of the language processing system. However, people can also imitate motor behaviour and such imitation is motivated by the social gains it brings to the imitator: partners who are imitated favorably evaluate the interaction, affiliate with the imitator, and show an increased willingness to help and cooperate. In three experiments, we investigated whether lexical imitation benefits the imitator in the same way. Pairs of participants engaged in a picture naming task. We manipulated whether participants' choices of names for objects were copied or not by their conversational partner. We asked whether being lexically imitated led participants to give a positive evaluation of the interaction and their partner, and encouraged them to cooperate in a subsequent interaction. Experiments 1 and 2 investigated these effects in a constrained single-word exchange between participants and found that imitated participants evaluated the interaction more favorably than counter-imitated participants. Experiment 3 involved a version of the task where participants were allowed to converse more freely and found that imitated participants showed a greater willingness to cooperate in a subsequent Public Goods game. These results suggest that imitation of language can bring social gains for the imitator. We interpret this as evidence that lexical imitation subserves the goal to maintain successful social relations.

2 INTRODUCTION

Imitation is an ability to copy the behaviour of others, and is pervasive in our social interactions. Look around you – two colleagues chatting in the corridor lean against the wall like reflections of each other, a passer-by talking on the phone is picking up a foreign accent, friends over lunch keep using the same words over and over again, and in the hip café around the corner everyone looks and talks much alike. While interacting, people tend to copy each other's motor behaviour (e.g., gestures, posture; henceforth, *behavioural imitation*) and language (e.g., word choice, accent; henceforth, *linguistic imitation*). But why do we imitate? One explanation that has been put forward to account for behavioural imitation is that imitation fosters social interactions and helps us to bond, therefore serving the goal of affiliating with others (Lakin, Jefferis, Cheng, & Chartrand, 2003). According to this account, being imitated induces a feeling of rapport with the imitator and encourages a favorable evaluation of the interaction.

Could linguistic imitation serve the same purpose? If people imitate each other's language in order to affiliate, we would expect linguistic imitation to bring about similar benefits as behavioural imitation. In three experiments, we manipulated whether participants' choices of names for objects were copied or not by their conversational partner. We asked whether being imitated in this way led participants to give a positive evaluation of the interaction, a positive evaluation of their partner, and encouraged them to cooperate in a subsequent interaction.

2.1 Imitating Language

People tend to imitate each other from a very early age. New-born babies can already imitate a wide range of behaviours, including tongue protrusion, head movements and facial expressions (Meltzoff & Moore, 1983; Meltzoff, 2002; Termine & Izard, 1988; cf. Ray & Heyes, 2011). Imitation manifests itself in how children learn (Bandura, 1977; Paulus, 2014), and in daily interactions with adults and peers (Meltzoff & Williamson, 2013). Importantly, the tendency to copy others remains pervasive throughout the lifespan. For example, adults imitate the body posture (LaFrance, 1982; Tia, Saimpont, Paizis, Mourey, & Fadiga, 2011), handshake angle and speed (Bailenson & Yee 2007), mannerisms (Chartrand & Bargh 1999; Lakin & Chartrand 2003; Lakin, Chartrand, & Arkin, 2008), and facial expressions of their

interaction partners (Bavelas, Black, Lemery, & Mullett, 1986; Dimberg, Thunberg, & Elmehed, 2000).

In this paper we focus on the tendency to imitate language. In conversation, people spontaneously imitate various characteristics of each other's language, including speech rate (Webb, 1969), timing and duration of pauses (Cappella & Planalp, 1981), tone of voice (Smith-Genthôs, Reich, Lakin, & de Calvo, 2015), voice pitch (Gregory & Webster, 1996), pronunciation (Pardo, 2006), and accent (Giles, Coupland, & Coupland 1991). Moreover, psycholinguistic experiments have shown that interlocutors imitate each other's sentence structure. For example, Branigan, Pickering, and Cleland (2000) found that participants spontaneously reproduced the grammatical structure that their partner had previously used in speech. Importantly, participants did so even though there was an alternative structure they could have used without affecting the meaning of their utterance. Similar results have been obtained when participants responded to a recording of somebody speaking (Bock, Dell, Chang, & Onishi, 2007) or to a written chat message (Hartsuiker, Bernolet, Schoonbaert, Speybroeck, & Vanderelst, 2008).

But perhaps the most striking example of linguistic imitation comes from studies showing that people imitate each other's word choice. For instance, Garrod and Anderson (1987) found that participants converged on the same words to name objects, while Brennan and Clark (1996) observed that participants consistently used the names they had previously converged on also in subsequent conversations with the same partner. Interestingly, people imitate their partner's lexical choice across different circumstances, and even if it requires them to use a word that would not normally use. In another study, Branigan, Pickering, Pearson, McLean, and Brown (2011) showed that participants imitated their interlocutor both if they had used a strongly favored (e.g., *bus*) or a strongly disfavored name for a picture (e.g., *coach*). Moreover, this effect occurred for spoken and text-based interactions, and regardless of whether the partner was a human or a computer. The tendency to imitate a partner's word choice is found in children's as well as adults' conversations (Branigan et al., 2016; Garrod & Clark, 1993).

Researchers in the psychology of language have argued that the tendency to converge, or *align*, on language has a foundation in automatic priming processes that affect the accessibility of linguistic representations in the language processing system (Pickering & Garrod, 2004).

Importantly, this tendency is mediated by speakers' beliefs about the partner. Thus, interlocutors have a general tendency to align on language, but they are even more likely to do so under certain conditions. For example, people imitate their partner more often if they perceive the partner to have low communicative competence (Branigan et al., 2011). Similarly, there is some evidence that interlocutors engage in more syntactic imitation when interacting with a likable conversational partner (Balcetis & Dale, 2005; Lev-Ari, 2015), or a partner who speaks with an accent perceived to be standard in a given speaker's community (Weatherholtz, Campbell-Kibler, & Jaeger, 2014).

There are different explanations for how beliefs might mediate the tendency to align on language. With regard to lexical alignment, it has been proposed that interlocutors pursue the goal of achieving communicative success, and that their beliefs about the partner serve as cues to select an utterance that is most likely to be understood. On this view, people engage in more imitation if they believe that it will help them achieve a shared representation of the situation with their partner (Branigan, Pickering, Pearson, & McLean, 2010). However, this explanation focuses on the role of the language processing system, and does not consider that linguistic imitation might have an impact on social interactions in which it occurs.

2.2 Social Consequences of Imitation

There is a long-standing hypothesis that imitation is linked to the ability to empathise and affiliate with others (Bavelas, Black, Lemery, & Mullett, 1987). Early evidence from correlational and field studies suggested a link between behavioural imitation and the level of affiliation and rapport with the interaction partner (see Chartrand & van Baaren, 2009 for review). For example, Charney (1966) observed that an increase in postural similarity between a psychotherapist and a client was correlated with an increase in rapport. Similarly, La France (1979) found that students reported greater rapport when interacting with a teacher who imitated them.

More recently, experiments in social psychology have confirmed that behavioural imitation brings about positive consequences for the imitator (see Chartrand & Lakin, 2013). In Chartrand and Bargh (1999), participants interacted with a confederate who either imitated their movements and posture or sat still in a neutral position. The imitated participants

evaluated the confederate as more likable and the interaction as more smooth as compared to the participants that were not imitated. Numerous studies have shown similar results when imitation was performed by a confederate (Kouzakova, Karremans, van Baaren, & van Knippenberg, 2010a; Kouzakova, van Baaren, & van Knippenberg, 2010b; Sanchez-Burks, Bartel, & Blount, 2009; Stel, Rispens, Leliveld, & Lokhorst, 2011), but also when it was carried out by another participant (Stel & Vonk, 2010), a virtual agent (Bailenson & Yee, 2005; Hasler, Hirschberger, Shani-Sherman, & Friedman, 2014; Verberne, Ham, Ponnada, & Midden, 2013) or a robot (Bailenson & Yee, 2007).

Moreover, behavioural imitation encourages the imitated person to be helpful and to cooperate with others. Van Baaren, Holland, Kawakami, and van Knippenberg (2004) found that participants were more likely to spontaneously help a confederate pick up pens from the floor if she imitated their body posture beforehand. Furthermore, they were more willing to help a stranger and donated more money to a charity than those who were not imitated. Similarly, imitated participants were more likely to respond to requests for help (Guéguen, Martin, & Meineri, 2011), and preschool children more often helped (Carpenter, Uebel, & Tomasello, 2013) and trusted (Over, Carpenter, Spears, & Gattis, 2013) an experimenter who imitated them.

2.3 Does Linguistic Imitation Benefit the Imitator?

In this paper, we ask whether linguistic imitation can bring about similar benefits as behavioural imitation. Crucially, there is already some evidence that imitation of language has a positive effect on social interactions. For example, imitating the accent of an unfamiliar speaker leads to a more positive evaluation of this speaker (Adank, Stewart, Connell, & Wood, 2013; Adank, 2015). In addition, correlational studies suggest that high language style matching between interlocutors is related to relationship stability (Ireland & Pennebaker, 2010), high group cohesiveness (Gonzales, Hancock, & Pennebaker, 2010), and a more favorable evaluation of the conversational partner (Manson, Bryant, Gervais, & Kline, 2013), whereas the degree of phonetic convergence is related to self-reported closeness between speakers (Pardo, Gibbons, Suppes, & Krauss, 2012).

Furthermore, copying the language of others can also have direct positive consequences for the imitator. In one study, a waitress received larger tips when she repeated her customer's order as opposed to simply acknowledging it (van Baaren, Holland, Steenaert, van Knippenberg, 2003). Similarly, participants who were instructed to imitate the language of their partners obtained higher individual gains in a negotiation task than those in a control group (Swaab, Maddux, & Sinaceur, 2011). Further evidence from field studies showed that passers-by approached on a street were more likely to help a confederate who verbally imitated them than a confederate who was responsive but did not imitate (Fischer-Lokou, Martin, Gueguen, & Lamy, 2011; Müller, Maaskant, van Baaren, & Dijksterhuis, 2012).

2.4 Why Do We Imitate Each Other? The Affiliative Goal Hypothesis

Early findings showing the benefits of imitation have been interpreted as evidence that people engage in imitation to satisfy the goal to affiliate with others (Lakin, Jefferis, Cheng, & Chartrand, 2003). As social animals, humans have a strong need to seek positive relations with others (Baumeister & Leary, 1995) and to maintain an optimal level of social belongingness (Brewer, 1991). Imitation has been advanced as an evolutionary adaptive behaviour that serves this need by smoothening interactions, promoting prosocial actions, and fostering bonds between people. According to this account, humans imitate others because it helps them to form and maintain positive social relationships (Chartrand & van Baaren, 2009; Kouzakova, van Baaren, & van Knippenberg, 2010b; Lakin, Jefferis, Cheng, & Chartrand, 2003; Over & Carpenter, 2013; Yabar, Johnston, Miles, & Peace, 2006).

To this date, evidence for this claim comes predominantly from research in social psychology and concerns behavioural imitation. Psycholinguistic studies investigating the affiliative goal hypothesis are scarce. Moreover, much of the work on linguistic imitation used paradigms that did not allow causal inferences. This poses difficulty for the interpretation of some of the relevant findings. For example, in one study participants who used similar language more often cooperated with each other in a coordination game (Scissors, Gill, & Gergle, 2008). However, this association was correlational and so we do not know whether cooperation was caused by imitation or vice versa. For the same reason, other correlational studies should be interpreted with caution (e.g., Ireland & Pennebaker, 2010).

The hypothesis that linguistic imitation benefits the imitator has also been investigated using experimental manipulations. However, these experiments did not allow conclusions to be drawn about the exact locus of any effects. For example, in one of the studies that found being imitated encourages helping behaviour, a confederate was instructed to imitate both the language and the motor behaviour of passers-by or to refrain from imitating (Müller et al., 2012). Importantly, we cannot be certain which type of imitation (or both) led to helping behaviour. Other studies manipulated specifically imitation of language, but the instructions for the imitator did not specify what aspect of language to imitate, or how often imitation should be performed. Such studies remain inconclusive with regards to whether the observed effects are driven by imitation of all or some aspects of language (e.g., Fischer-Lokou et al., 2011; Swaab et al., 2011; cf. Scissors, Gill, Geraghty, & Gergle, 2009).

2.5 Research Overview

To our knowledge, there are no controlled experiments that demonstrate unambiguously that linguistic imitation fosters social interaction, cooperation, and bonding in the same way as behavioural imitation. In this paper, we present three studies that set out to bridge this gap. Combining methods used in psycholinguistics and social psychology, we created a novel experimental paradigm that allowed us to investigate the effects of linguistic imitation in a carefully controlled manner. We used a between-participants design to examine how being linguistically imitated versus not being linguistically imitated (henceforth, counter-imitated) by a conversational partner affected participants' judgments of the quality of an interaction, their perceptions of their partner, and their cooperative behaviour in subsequent interactions with the partner.

In contrast to much previous work that investigated the effects of imitating several different aspects of language at once, we focused on the interlocutor's lexical choice. We manipulated this aspect because the choice between alternative words is salient for the interlocutors and therefore lexical imitation may be particularly likely to affect social-affective mechanisms, and because of the extensive psycholinguistic literature on lexical imitation (e.g., Brennan & Clark, 1996). Additionally, our experiments used a computerised paradigm, in contrast to

previous studies that used paradigms involving a confederate or a participant who was instructed to imitate (see Kuhlen & Brennan, 2013, for a critique of confederate studies).

In the experiments, pairs of naïve participants engaged in a computerized picture-naming task. Participants alternated naming a picture for their partner (e.g., *mitten*, where the partner had to choose between a mitten and a butterfly), and responding to their partner naming a picture (e.g., by matching a picture to the name provided by the partner). On some trials, their partner named a picture that the participant had already named on a previous turn. Crucially, the partner's responses on these trials were manipulated by a computer so that the partner appeared to imitate or counter-imitate their partner's earlier word choice. For participants in the *imitation* group, their partner appeared to use the same name as the participant used previously (e.g., *mitten*). But for participants in the *counter-imitation* group, their partner appeared to use a different (though appropriate) name for the picture (e.g., *glove*). Having completed the naming task, participants filled out a questionnaire evaluating the interaction and their partner. Finally, they played a short decision-making game to measure their willingness to cooperate with each other in subsequent interactions.

If people engage in linguistic imitation in order to foster their relationships with others, we would expect clear social benefits to arise for the imitator as a result of imitating their interlocutor's word choice. In accord with previous research and the affiliative goal account, we expected lexical imitation to affect both the participants' self-reported evaluation of the interaction and the partner, and their behaviour in a subsequent unrelated interaction with the same partner. We predicted that participants who had been imitated should evaluate the interaction and their partner more positively than participants who had been counter-imitated. Furthermore, we expected that participants who had been imitated would show a greater willingness to cooperate with their partner in a subsequent decision-making game that had consequences for their earnings from the experiment.

3 EXPERIMENT 1

Experiment 1 investigated these predictions in a constrained context of single-word text exchanges. We used a computerized paradigm that allowed us to introduce our manipulation in a carefully controlled manner, keeping the timing, frequency, and content of imitation

consistent across participants. Thus, it allowed us to focus precisely on the effects of imitating a lexical choice.

Pairs of participants engaged in a picture naming task where they took turns typing a name for a picture into the computer screen, and matching a picture to a name. Participants were led to believe that they interacted with each other, but in fact their partner's responses were generated by a computer program that made it seem that their partner either consistently imitated or consistently counter-imitated the participant's previous lexical choice for the picture.

Next, the participant evaluated the smoothness of the interaction and the likability of the partner. Finally, we recorded whether the participant made a cooperative or individualistic decision in a one-shot Stag Hunt game (Skyrms, 2004). Stag Hunt is a coordination game used in experimental economics to investigate factors that influence human decision-making and cooperation (Devetag & Ortmann, 2007; Rankin, Van Huyck, & Battalio, 2000). In a typical Stag Hunt, two players choose between making an individualistic decision that results in a low but certain gain for the individual (i.e., hunt for a hare), and a cooperative decision that might bring a high gain for both individuals, but only if both players decide to cooperate (i.e., hunt for a stag). Crucially, participants' behaviour in Stag Hunt and other coordination games can be affected by social factors (e.g., Balliet, Wu, & Dreu, 2014). Coordination games have been previously used to measure cooperative behaviour in imitation research, although results are not always consistent (Manson et al., 2013; Scissors et al., 2008, 2009; Verberne et al., 2013).

In Experiment 1, we predicted that the participants who were imitated would more often make a cooperative decision in the Stag Hunt game than those who were counter-imitated. We also expected imitated participants to evaluate their partner as more likable and their interaction with the other person as more smooth than counter-imitated participants.

3.1 Methods

3.1.1 Participants

We recruited 48 (10 male, 38 female) native speakers of British English to take part in the study. Participants were recruited via the University of Edinburgh career service and promised

a minimum payment of £5. Participants were all current or recent students at the university. We asked participants to sign up for a session with another previously unacquainted person and to form same-gender pairs.

3.1.2 Materials

For the picture naming task, we used pictures from the Snodgrass and Vanderwart (1980) set. All pictures depicted objects that could be named using a single word in British English. We selected 17 target pictures with two balanced names, such that the frequency with which each name was used for the picture was between 30% and 55% (e.g., *mitten/glove*). Name frequencies for 8 of these pictures were obtained from Barry, Morrison, and Ellis (1997). We conducted a pretest to obtain name frequencies for the other 9 target pictures. In our pretest, 48 further native British English speakers provided names for twenty pictures from Snodgrass and Vanderwart. The pictures were printed on two sheets and handed to the participants individually. Participants were asked to name the pictures by writing a single word below each picture. We also selected 118 distractor pictures that had one dominant name which was used more than 80% of the time (e.g., *apple*). The distractors were selected based on the name agreement norms from Barry et al.

We constructed 34 experimental items consisting of a target picture and a distractor, as well as 42 filler items consisting of two distractor pictures (34 fillers were used in the main task and 8 fillers were used in a practice session). During the picture naming task, each target picture appeared twice and each distractor picture appeared once. The picture naming task was implemented using OpenSesame 3.0 (Mathôt, Schreij, & Theeuwes, 2012).

3.1.3 Procedure

Participants came to the lab in pairs. They were greeted by the experimenter, taken into a room together, and given consent forms. The consent forms stated that participants would receive at least £5 for completing the study, with a possibility of obtaining an additional monetary reward if they choose to engage in a “bonus round” and play the Stag Hunt game. Next, the experimenter introduced himself briefly by mentioning his name and degree program, and asked the participants to do the same. Participants would typically reply by mentioning their

name, degree, and year of studies. The purpose of this brief spoken introduction was to provide a minimal social context for the following interaction. After the introduction, participants were led to separate rooms where they remained until the end of the study.

Participants sat in front of a computer screen and read the instructions for the picture naming task. The instructions explained they would take turns naming pictures and matching pictures to a name and that they would perform the task together with the other person over the network connection. Participants were instructed to name each picture with a single word. When the participants were ready to start, the experimenter closed the doors and the task began.

The task consisted of 34 experimental and 34 filler trials, organised in a sequence where there were two filler trials between each experimental trial (e.g., [1] experimental trial, naming turn; [2] filler, matching turn; [3] filler, naming turn; [4] experimental trial, matching turn, etc.). On each trial, two pictures appeared on the screen. If it was a naming turn, participant saw a message asking them to name either the left or the right picture, and a text box appeared at the bottom of the screen. The participant typed the name for the indicated picture into the text box. If it was a matching turn, a name for one of the pictures appeared below the pictures, and the participant saw a message asking them to use the arrow keys to select the picture that matched the name. At the end of each trial they saw a feedback message indicating whether the correct picture had been selected.

Participants were told that the name that they provided on a naming turn was sent to their partner in the other room. Similarly, they were told that the name that appeared below the pictures on the matching turn was provided by their partner. Thus, they were led to believe that they were carrying out the task interactively with their partner. In fact, there was no network connection between the two rooms and participants interacted with a preprogrammed computer script. The response time on the partner's matching turn varied between 3500 and 4500ms and on the naming turn varied between 5000 and 6000ms (i.e., to make it appear that the responses were produced by the partner).

Both participants in a pair were randomly assigned to either the imitation or counter-imitation condition. The experimenter was blind to condition during the session. In the imitation condition, the computer recorded the name entered by the participant for the target picture

when it first appeared on participant's naming turn (e.g., *mitten*). Then, when the target picture reappeared on a matching turn, the computer displayed this name (*mitten*). It therefore seemed as though the partner was responding with the same name. Importantly, the computer displayed the name as it had been spelled by the participant. Therefore, it also seemed that the partner used the same spelling as the participant.

In the counter-imitation condition, the computer recorded the name entered by the participant and compared it with the names for the target picture stored in its memory. For each target picture, it stored two words that had been identified in the pre-test as alternative names for this picture (e.g., *mitten/glove*). The computer first checked if the name entered by the participant matched the word that had been identified in the pre-test as the more frequent of the alternative names (e.g., *mitten*). If it matched, then the computer displayed the other name as the partner's response (e.g., *glove*). If it did not match, then the computer displayed the more frequent name.¹⁶ It therefore seemed as though the partner was responding with a different (though appropriate) name than the one previously used by the participant (Figure 5). The picture naming task was preceded by a practice session of 8 filler items. The task took approximately 30 minutes.

¹⁶ Note that our manipulation was sensitive to the spelling of the word entered by the participant. For example, the faithful copying of the participant's spelling in the imitation condition could lead the participant to believe that their partner was copying their accidental mistakes (e.g., *miten* instead of *mitten*). Furthermore, in the counter-imitation condition an unusual spelling (e.g., *miten*) could render it impossible for the computer to correctly identify the name used by the participant as an instance of the more frequent of the two names for the target picture (e.g., *mitten*). In such cases, the computer would display the more frequent name, effectively imitating the participant's lexical choice. But crucially, spelling mistakes occurred in fewer than 6% of all the data (equally distributed between conditions).

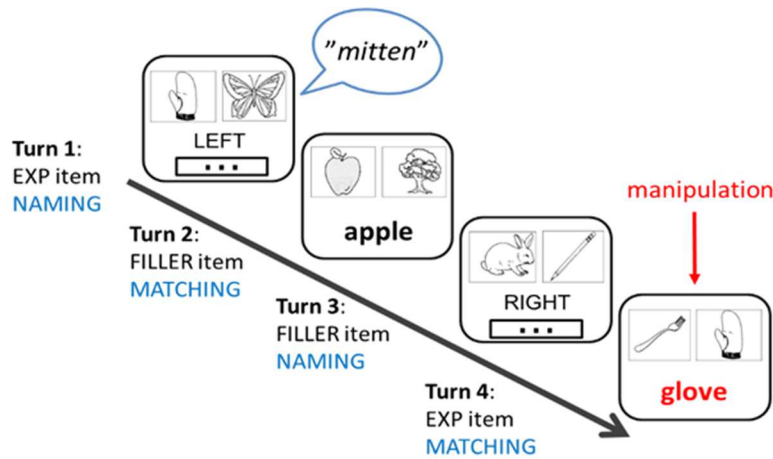


Figure 5. Experiment 1: An example of the experimental procedure in the counter-imitation condition.

After completing this task, participants saw a message asking them to fill out an anonymous questionnaire regarding their participation in the experiment. There were ten items in the questionnaire, two of which were the critical items that demonstrated effects of behavioural imitation in Chartrand and Bargh (1999). The critical items asked about the smoothness of the interaction (“*How smoothly would you say your interaction went with the other participant?*”) and the likability of the partner (“*How likable was the other participant?*”). As in Chartrand and Bargh, the remaining eight items were fillers asking about various aspects of the experiment (e.g., “*How well did the network connection work?*”; see Appendix C for a full list of items). All items were measured on a 1-9 Likert scale with anchors for the low and the high end (e.g., “*extremely awkward*” vs “*extremely smooth*”, “*extremely dislikeable*” vs “*extremely likable*”). Participants were instructed to fold the filled questionnaire and place it in a cardboard box nearby.

Next, participants saw another message inviting them to play the Stag Hunt game together with their partner. They were reminded that it constituted an additional part of the study that could earn them some extra money. If they agreed, the participants would proceed to read the instructions for the game. The rules for the game were as follows. The participant and their partner were hunters in the forest and there were two types of animals they could shoot. A hare was worth £1 and if they chose to hunt it they were guaranteed to get the reward. A stag was worth £4, but to hunt it down two hunters needed to shoot at the same time. If they did, they

would split the reward so that each received £2. However, in the event that one hunter decided to shoot the stag, but the other went for the hare, the first hunter would fail to hunt down the stag and get no reward, while the other one would still get £1 for the hare. Each hunter could shoot only once. Participants signalled their choice by typing “stag” or “hare” into a text box on the screen, and the game then ended. The questionnaire and the Stag Hunt game took about 5 minutes each.

At the end of the study, participants wrote their answers to three final questions, asking about the goals of the study (“*What do you think was the purpose of the experiment?*”) and probing what they noticed about their partner’s behaviour (“*What happened during the naming/matching game?*”) and “*Do you have any other comments regarding the experiment?*”). Finally, they were all paid £7, thanked, and debriefed. Overall, the experimental session lasted approximately 45 minutes.

3.2 Results

The responses to the final questions indicated that one participant suspected their partner was in fact a disguised computer program. The data from this participant were excluded from further analyses. Moreover, 62% of participants in the remaining sample reported noticing that they were imitated/counter-imitated during the picture-naming task. The number of participants who noticed being imitated/counter-imitated was not significantly different between conditions (54% in imitation, 70% in counter-imitation; $\chi^2(1, 47) = .62, p > .250$).

We compared the evaluations produced by participants in the imitation and counter-imitation condition for the two critical items from the questionnaire (i.e., asking about the smoothness of the interaction, and partner’s likability). We treated the evaluations as being measured at an ordinal level. We carried out an ordinal regression with the evaluation of the interaction as the dependent variable, and condition (imitation vs counter-imitation) and noticing (participant noticed vs not noticed being imitated/counter-imitated) as predictors.

Consistent with our predictions, participants evaluated the interaction as more smooth in the imitation than in the counter-imitation condition ($\beta = 2.44, t = 2.48, p = .013$). There were no effects of whether participants noticed being imitated/counter-imitated (no simple effect: $\beta =$

.48, $t = .58$, $p > .250$; and no interaction between this predictor and condition: $\beta = -1.79$, $t = -1.50$, $p = .133$).

We carried out a similar ordinal regression model on the evaluations of partner's likability. However, we found no significant difference in the evaluations of partner's likability between conditions ($\beta = .55$, $t = .63$, $p > .250$) (Figure 6). In addition, there were no effects of whether participants noticed being imitated/counter-imitated (no simple effect: $\beta = -.71$, $t = -.84$, $p > .250$; and no interaction: $\beta = -.09$, $t = -.08$, $p > .250$).

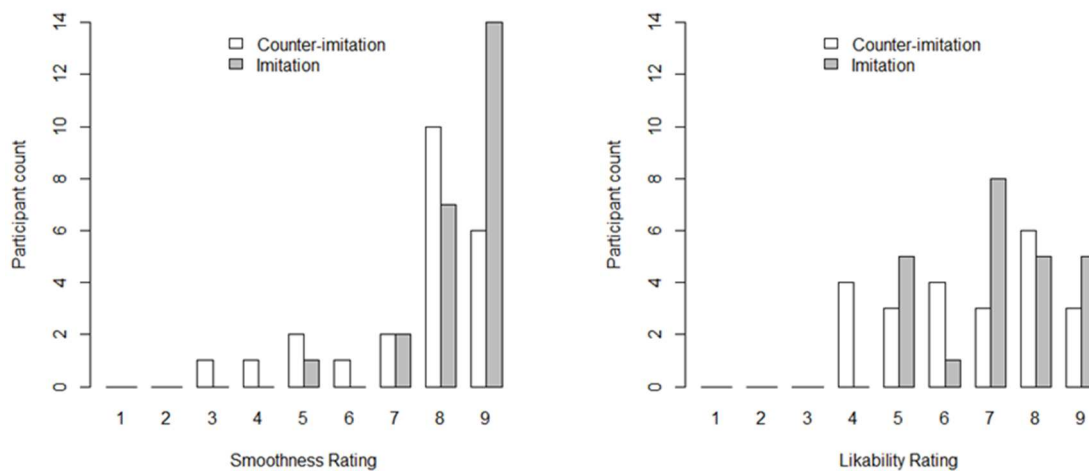


Figure 6. Experiment 1: Histograms showing the spread of ratings produced by the participants. The graph on the left shows the data for the item measuring the smoothness of the interaction, the graph on the right for the item measuring the partner's likability.

Next, we looked at participants' responses in the Stag Hunt game in order to investigate participants' willingness to cooperate. We observed a high rate of missing data in both the imitation and counter-imitation conditions (7 and 6 missing observations, out of 24 in each condition). This may have occurred because the Stag Hunt game was framed as an additional task and so some participants chose not to engage in it. The remaining data were analysed using a Fisher's exact test. We compared the frequency of each decision (stag/hare) between conditions. Numerically, more people chose to cooperate with the other person in the imitation condition (14 stag, 3 hare) than in the counter-imitation condition (11 stag, 6 hare). However, this association was not significant ($p > .250$). We also compared the frequency of each

decision between the participants who noticed versus not noticed being imitated/counter-imitated. More people chose to cooperate in the group that noticed (18 stag, 2 hare) than in the group that did not notice being imitated/counter-imitated (7 stag, 7 hare; $p = .017$).

3.3 Discussion

Experiment 1 provided some evidence that lexical imitation fosters social interactions between people. In line with one of our predictions, we found that participants who were lexically imitated evaluated their interaction with the other person as more smooth as compared to those who were counter-imitated. However, we found no effect of imitation on the evaluation of partner's likability, or on the participants' choice of a cooperative response in the Stag Hunt game.

The conclusions that can be drawn from Experiment 1 are limited in important respects. First, the evaluations of the interaction and the partner were obtained by single-item measurement, following some previous studies on imitation (e.g., Chartrand & Bargh, 1999; Kouzakova et al. 2010a, 2010b). However, using single-item measures can have a negative impact on measurement reliability and lead to both type I and type II errors (Credé, Harms, Niehorster, & Gaye-Valentine, 2012). In Experiment 2, we therefore carried out the same imitation/counter-imitation manipulation using the same picture-naming and -matching task as in Experiment 1, but introduced a new multi-item questionnaire as a measure of participants' evaluations of the interaction and the partner.

Second, in Experiment 1 participants were briefly introduced to each other at the beginning of the session so there would have been variability in their impressions of their partner (i.e., some participants could have liked their partner more than others before engaging in picture naming task). Impressions about partner's warmth and likeability form very early in interactions (e.g., Asch 1946; Willis & Todorov, 2006). Furthermore, implicit impressions about others are difficult to undo (see Mann & Ferguson, 2015). This might have led to the lack of an effect of the experimental manipulation on the evaluation of partner's likeability, in contrast to its effect on the evaluated smoothness of the interaction. Therefore, in Experiment 2 we provided all

participants with the same type of information about their partner and, crucially, participants did not interact at the beginning of the experimental session (although they saw each other).

Finally, in Experiment 2 we replaced the one-shot Stag Hunt game with a repeated Public Goods Game (PGG). PGG is widely used in research on human cooperation (Camerer, 2003; Rand, & Nowak, 2013), because it closely reflects the dynamics of everyday human interactions (Hardin, 1968; Rand, Dreber, Ellingsen, Fudenberg, & Nowak, 2009). Typically, PGG involves two or more players who on each turn decide how many credits to invest into a common pool. High payoff can be achieved by either cooperating with the other player (both players contribute to the pool) or by defaulting on the other player (keeping one's credits, while the other player contributes). Thus, PGG allowed us to measure the participants' willingness to cooperate with their partner on a continuous scale, with multiple observations. In addition, the instructions in Experiment 2 did not treat the PGG as an optional task, in order to reduce or eliminate missing data.

4 EXPERIMENT 2

In Experiment 2, we replaced the spoken introduction with a computer message that contained information about the other participant. Then, participants engaged in the same picture-naming task as in Experiment 1, during which the computer either imitated or counter-imitated their lexical choices. After the task, participants filled out two questionnaires: the short questionnaire from Experiment 1, and a new questionnaire that contained multiple items asking for an evaluation of the interaction and the partner.

Next, participants played six turns of a Public Goods Game. We chose to keep the participants blind regarding the outcome of each turn to prevent their behaviour being affected by the outcome of the previous turn (e.g., Engelmann & Fischbacher, 2009), rather than reflecting the willingness to cooperate caused by imitation or counter-imitation in the picture-naming task. Blind set-ups have been shown to yield similar results to standard information set-ups (Burton-Chellew & West, 2013).

In Experiment 2, we predicted that participants in the imitation group would provide more positive evaluations of the interaction and the partner, as compared to the counter-imitated

group. Additionally, we predicted that they would exhibit more cooperative behaviour in the PGG (by contributing more to the common pool).

4.1 Methods

4.1.1 Participants

We recruited 64 (20 male, 44 female) further native English speakers (46 British English). Participants were recruited from the same population as in Experiment 1 and agreed to take part on a voluntary basis. Similarly to Experiment 1, participants were asked to sign-up with another previously unacquainted person of the same gender.

4.1.2 Materials

The materials in the picture naming task were the same as in Experiment 1. To measure the evaluations of the interaction and the partner, we used the short questionnaire from Experiment 1. In addition, we introduced a new questionnaire to access the participants' evaluations using multiple items. It consisted of 6 items developed to evaluate the interaction and 11 items taken from the Reysen Likability Scale (RLS). The RLS was designed specifically to measure liking of the other person and has good psychometric characteristics (Reysen, 2005). The RLS items and items measuring the evaluation of the interaction were intermixed. All items were measured on a 1-9 Likert scale with anchors for the low and the high end ("*very strongly disagree*" vs "*very strongly agree*"). The full list of items can be found in Appendix C.

4.1.3 Procedure

Two participants were scheduled for each session. Participants were met by the experimenter at two distinct locations so that they did not interact before the beginning of the session. They were then led to the lab together. During this time, they listened to the experimenter telling them about the facilities in the lab and did not talk with each other. On arrival, participants were seated in front of a computer screen in separate rooms and signed the consent forms stating that they agreed to participate on a non-paid basis. The consent forms mentioned that

participants would play a decision game and that they might earn between £1-4 as a result of the game.

Participants answered demographic questions by typing their responses into the computer and then saw a message about the partner they would be interacting with. The message contained the same type of information that the participant gave in response to the demographic questions (i.e., the other person's name, gender, dialect, year and course of studies). Next, participants engaged in the picture naming task from Experiment 1. After the task, they saw a message asking to fill out a questionnaire about their participation in the study. First they answered the short questionnaire from Experiment 1, followed by the new multi-item questionnaire asking about the partner and the interaction. The questionnaires were computerized and the answers were saved automatically after completion.

Participants then read the instructions for the Public Goods game. The instructions explained they would play several turns of an investment game together with the other person. Participants were not told how many turns there would be. On each turn, each player would be given 40 credits that they could invest into a common pool. The amount in the pool would be multiplied by some factor and then divided between the two players at the end of the turn. The instructions did not specify the size of the multiplication factor. The payoff from each turn consisted of the earnings from the pool plus the credits the participant decided to keep. The participants were told that each credit was worth 5p and at the end of the game the payoff from one turn would be picked at random and paid to them. In order to make sure that the participants considered different outcomes, they were asked to spend some time thinking about the possible decisions and their outcomes before starting the game.

Participants played six turns of the game. The multiplication factor varied between turns. For turn one, we used a factor of *1.9*. The factors for the remaining five turns were: *1.5*, *1.7*, *1.9*, *2.1*, *2.3*, presented in a randomised order.¹⁷ We used a fixed factor on turn one, but randomised

¹⁷ Each participant in a pair had a different order of the multiplication factors. Each of these orders was yoked to a participant in the other condition (e.g., pair 1, imitation; participant 1:

the order of the factors on turns two to six, so that we could analyse turn one on its own and also analyse all six turns together. We did so in case the effect of the imitation/counter-imitation manipulation would turn out to be highly transient. On each turn, the multiplication factor was shown on top of the screen and a text box appeared below. Participants typed the number of credits they wished to invest into the text box. After they had done so, the next turn started. Participants were not informed about the outcome of a turn. Moreover, they were not informed about their payoff from the game until the end of the experiment. After the PGG, participants answered the same three final questions as in Experiment 1. They were then thanked, debriefed, and paid £4 (regardless of their decisions in the PGG).

4.2 Results

We excluded four participants who reported suspecting that the partner's responses in the picture naming task were generated by a computer program. In addition, 52% of the remaining participants reported they were imitated or counter-imitated during the picture naming task. The number of participants who reported being imitated/counter-imitated did not significantly differ between conditions (42% in imitation, 59% in counter-imitation; $\chi^2(1, 60) = 1.02, p > .250$).

In order to obtain composite measures of the evaluation of the interaction and the partner, we first subjected all items from the new questionnaire (17 items) and the likability and smoothness items from the old questionnaire (2 items) to a confirmatory Principal Component Analysis (with varimax rotation). We extracted two components that together accounted for 63% of variance. Next, we dropped two items with very similar loadings on both components ($<.10$ difference). Such items do not introduce any distinctive information to the component

1.5, 1.7, 1.9, 2.1, 2.3, participant 2: 1.7, 1.5, 2.1, 1.9, 2.3; pair 2, counter-imitation; participant 3: 1.5, 1.7, 1.9, 2.1, 2.3, participant 4: 1.7, 1.5, 2.1, 1.9, 2.3).

scores and it is a common practice to exclude them (e.g., Möttus et al., 2012). The remaining seventeen items had high component loadings (>.50).

Table 7

The Final Two-Component Solution of the Questionnaire Items in Experiment 2

	Partner	Current Interaction	h^2
This interaction was satisfying	0.51	0.62	0.64
This interaction was pleasant	0.53	0.72	0.80
I would rate the level of rapport we had as high	0.29	0.78	0.70
This interaction made me feel at ease	0.23	0.78	0.66
How smoothly would you say your interaction went with the other participant	-0.03	0.79	0.63
I would ask this person for advice	0.73	0.07	0.54
This person is knowledgeable	0.65	0.09	0.43
This person is warm	0.80	0.37	0.77
This person is likeable	0.81	0.38	0.80
This person is approachable	0.59	0.45	0.55
I would like this person as a coworker	0.75	0.34	0.69
I would like this person as a flatmate	0.79	0.17	0.65
This person is friendly	0.80	0.36	0.77
I would like to be friends with this person	0.79	0.35	0.75
This person is physically attractive	0.54	0.14	0.32
I would like to have interactions like this on daily basis	0.74	0.18	0.57
I would enjoy having other interactions like this	0.60	0.42	0.54
<i>Variance explained</i>	<i>41%</i>	<i>23%</i>	

Note. h^2 = communality. Loadings on the predominant component are shown in bold.

The analysis resulted in a final two-component solution that explained 64% of variance (Table 7). The first component consisted mostly of items related to the evaluation of the partner, whereas the second component consisted of items asking about the evaluation of the current interaction with the other person. We interpreted them as the *Partner* and the *Current Interaction* component, respectively. For each participant, we calculated the evaluation of the partner by averaging the scores for the items loading on the *Partner* component. In the same manner, we calculated the evaluation of the interaction by averaging scores for the items on the *Current Interaction* component.

First, we compared the evaluation of the interaction between conditions. We carried out a 2 X 2 between-participants ANOVA on the mean scores on the *Current Interaction* component,

with Condition (imitation vs counter-imitation) and Noticing (participant reported vs did not report being imitated/counter-imitated) as factors. Importantly, we found a main effect of Condition, suggesting that participants evaluated the interaction with the other person more positively in the imitation than in the counter-imitation condition ($M = 7.11$ vs $M = 5.90$; $F(1, 56) = 8.92$, $p = .004$, $\eta_G^2 = .14$). There were no effects of Noticing (no main effect: $F(1, 56) = 3.41$, $p = .070$, $\eta_G^2 = .06$; and no interaction between Noticing and Condition: $F(1, 56) = .62$, $p > .250$, $\eta_G^2 = .01$).

We also compared the evaluation of partner between conditions. We carried out a similar 2 X 2 ANOVA on the mean scores on the *Partner* component. However, we found no main effect of Condition, indicating that imitated participants did not evaluate their partner more positively than those who were counter-imitated ($M = 5.89$ vs $M = 5.77$; $F(1, 56) = .08$, $p > .250$, $\eta_G^2 < .01$). There were also no effects of Noticing (no main effect: $F(1, 56) = .15$, $p > .250$, $\eta_G^2 < .01$; and no interaction between Noticing and Condition: $F(1, 56) = 1.93$, $p = .170$, $\eta_G^2 = .03$).¹⁸

Next, we analysed the mean contributions to the common pool in the Public Goods game. We carried out a 2 X 2 between-subjects ANOVA on mean contributions across all turns, with Condition and Noticing as factors. We found no effect of Condition, suggesting that imitated participants did not contribute more than those who were counter-imitated ($M = 23.61$ vs $M = 23.56$; $F(1, 56) = .05$, $p > .250$, $\eta_G^2 < .01$). Both groups contributed approximately 59% of their total amount of credits. Moreover, mean contributions were not affected by whether participants noticed being imitated/counter-imitated (no main effect: $F(1, 56) = 1.73$, $p = .194$,

¹⁸ Note that, unlike in Experiment 1, in Experiment 2 we did not perform separate analyses for the likability and the smoothness item from the short questionnaire. This is because we expected these items to load on the same components as the items from the new multi-item questionnaire (i.e., we designed the new questionnaire to measure the evaluation of the partner and interaction). Therefore, in Experiment 2 we included the likability and the smoothness item in PCA together with the items from the new questionnaire and we report the analyses for the average scores of all items loading on a given component.

$\eta_G^2 = .03$; and no interaction: $F(1, 56) = 1.96$, $p = .167$, $\eta_G^2 = .03$). We found the same pattern of results for mean contributions on turn one only (see Appendix C).

4.3 Discussion

Experiment 2 replicated the findings of Experiment 1: Participants whose lexical choices were imitated evaluated the interaction more positively as compared to those who were counter-imitated. We did not find any effects of lexical imitation on the evaluation of the partner and the willingness to cooperate, despite using the multi-item questionnaire which we expected to improve the reliability of both measures (Credé et al., 2012). We can therefore be more confident that our manipulation of imitation does not affect the evaluation of partner's likeability and the willingness to cooperate in subsequent interactions.

An alternative possibility is that the constrained or limited nature of the interaction provided by picture naming prevented it from being treated as a socially relevant form of interaction, so that it affected ratings of the interaction itself but had no impact on social consequences of the interaction (relating to the assessment of one's partner or to pro-social behaviour more generally). To bring about such effects, people might need to converse in a manner that was less constrained by the task than is the case when producing single-word responses, and which is much more similar to typical everyday conversation. In such conversation, the interlocutors more clearly make a commitment to the minimization of communicative effort (Clark, 1996) and, of course, make extensive use of linguistic imitation (Pickering & Garrod, 2004). In Experiment 3, we therefore employed a more naturalistic set-up that allowed participants to converse freely while they performed a task.

5 EXPERIMENT 3

In Experiment 3, pairs of participants engaged in a modified version of the picture naming task. Participants communicated with each other via a text chat. They were allowed to converse freely, as long as they performed the task within the given time constraints. Their lexical choices were again manipulated by a computer program so that in the imitation condition participants would see their partner use the same words to name the pictures, and in the counter-imitation condition would see their partner use different words, but no other aspects

of their language use were manipulated (cf. Mills, 2014). After the task, we measured the evaluation of the interaction and the partner, and participants' willingness to cooperate using the same measures as Experiment 2.

5.1 Methods

5.1.1 Participants

We recruited 68 (26 male, 42 female) further native speakers of British English from the same population as in Experiments 1-2. Participants were promised a minimum payment of £4. Participants signed up for a session with another previously unacquainted person of the same gender.

5.1.2 Materials

For the picture naming task, we used 17 target pictures and 102 distractor pictures from Experiments 1-2. We constructed 34 experimental items consisting of a target picture and three distractors, as well as 51 filler items consisting of four distractors. Each target picture was used in two experimental items. Each distractor picture was used in three different items (experimental or filler). We constructed 4 further filler items for the practice run. The task was implemented using a custom-made mode of the DiET chat tool (Mills & Healey, submitted). We also used the Public Goods game and the two questionnaires from Experiment 2.

5.1.3 Procedure

Participants were met by the experimenter at distinct locations and led to the lab, as in Experiment 2. They were seated in separate rooms in front of a computer and signed the consent forms. The consent forms stated that participants would receive at least £4 for completing the study, with a possibility of obtaining additional £1-4 in a decision game. Participants then answered questions about their name, gender, and year and course of studies, and saw a message giving them the same information with regards to their partner.

Next, participants read the instructions and performed the picture naming task using a text-based chat tool. Unlike in Experiments 1-2, they were connected over a network and actually interacted with each other. The chat tool allowed each participant to see their own and their partner's last utterance on the display. Participants alternated between naming pictures and responding to their partner naming a picture. On each trial, they saw four pictures in a grid. They were told that their partner saw the same pictures, but arranged differently. The participant that was tasked with naming a picture on this turn saw one of the pictures highlighted by a thick yellow outline. Their task was to tell the other person the name of the highlighted picture and its location in the grid. The other participant then responded by describing the location of this picture in their grid. If the locations matched, the responding participant was instructed to type "snap". There were no further constraints on participants' utterances, but after 30 seconds the turn would time out and the next turn would start automatically.

As in Experiments 1-2, the items in the picture naming task were organised so that the experimental items containing the same target picture appeared consecutively, separated by two filler items. There also was a filler item between the second of the two experimental trials and a following experimental item with a new target picture (Figure 7). Both participants in a pair were randomly assigned to either the imitation or the counter-imitation condition.

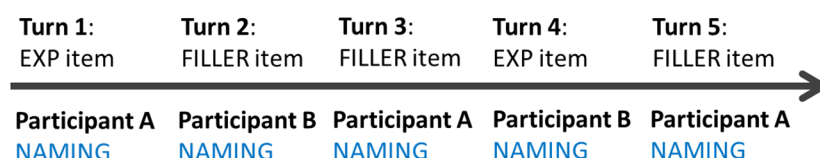


Figure 7. Experiment 3: The sequence of trials. There are two filler items between each appearance of the target picture. There is one filler item before the next sequence containing a new target picture.

Throughout the task, the chat tool scanned the participants' utterances and identified the names for the target pictures by comparing the input from participants against the list of names stored in its memory. The program kept track of the most recent name for a target picture typed by each participant and used this information to apply either the imitation or counter-imitation

manipulation.¹⁹ The manipulation was applied symmetrically so that each participant in a pair saw the other participant imitating (in the imitation condition) or counter-imitating their lexical choices (in the counter-imitation condition). However, for the sake of simplicity, in the following description we will adopt an asymmetric perspective and refer to one of the participants as *participant*, and the other as *partner*.

In the imitation condition, the program manipulated the display so that the participant saw their partner use the same name for a target picture that the participant had used before. The program did not intervene as long as the partner used the same name (e.g., participant: *mitten* → partner: *mitten*). However, if the partner used a different name than the participant had used before (participant: *mitten* → partner: *glove*), the program replaced the non-matching name (*glove*) with the name previously used by the participant (*mitten*) so that on their screen the participant would see their partner imitating their lexical choice (participant: *mitten* → partner: *mitten*). All other words in the utterance remained intact. Importantly, on their screen the partner saw their utterance unchanged (participant: *mitten* → partner: *glove*). This way, we hoped to keep both participants unaware of the substitution.

In the counter-imitation condition, the program manipulated the display to ensure that the participant saw their partner use different names for the target pictures. The program did not intervene if the partner spontaneously used a different name for a target picture. But if the partner used the same name to refer to the target picture as the participant had used before, the program manipulated the display of the partner's utterance and substituted the matching name actually used by the partner (*mitten*) with a non-matching name (*glove*), so that it would seem that the partner was counter-imitating the lexical choice of the participant. As in the imitation condition, the partner did not see the substitution on their screen (Figure 8). The picture naming task was preceded by 4 filler trials. The task took approximately 30 minutes.

¹⁹ Note that imitation/counter-imitation manipulation in Experiment 3 was sensitive to any unusual spelling in the same way as in the counter-imitation condition in Experiments 1-2.

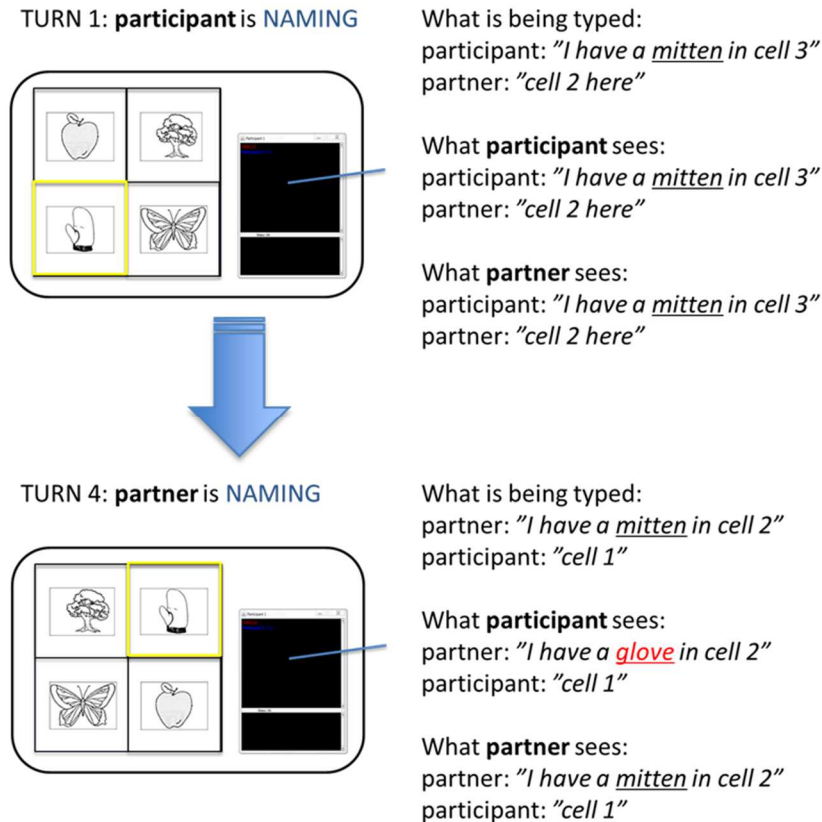


Figure 8. Experiment 3: An example of counter-imitation procedure for an experimental trial on Turn 1 (target picture is being named by participant) and Turn 4 (target picture named by partner).

After the task, participants filled out the questionnaires, and played the Public Goods game as in Experiment 2. Participants were promised a minimum of £4 for participating and up to £4 of additional earnings from the game. For the Public Goods game, we used the same set-up, instructions, and procedure as in Experiment 2. Participants then answered the three final questions from Experiments 1-2, were debriefed, and were paid £8 (regardless of their decisions in the game).

5.2 Results

No participants reported a suspicion that their partner's utterances were manipulated by the computer. Of all the participants, 14 participants (21%) reported they had noticed being

imitated/counter-imitated. We did not include noticing as a factor in the subsequent analyses due to this small number.

We used confirmatory Principal Component Analysis (varimax rotation) to obtain composite measures of the evaluation of the interaction and the partner. We extracted two components that explained 64% of the variance. Next, we removed five items that had similar loadings on both components (difference < .10), and one item that did not have high loadings on either of the components (we used the conventional criterion of < .35; Grice, 2001).

Table 8

The Final Two-Component Solution of the Questionnaire Items in Experiment 3

	Future Interactions and Partner	Current Interaction and Likability	h ²
This interaction was satisfying	0.55	0.66	0.74
This interaction was pleasant	0.50	0.75	0.81
This person is warm	0.54	0.70	0.77
This person is likeable	0.51	0.74	0.80
How likable was the other participant	0.11	0.84	0.71
How smoothly would you say your interaction went with the other participant	-0.01	0.55	0.31
I would like this person as a coworker	0.73	0.55	0.84
I would like this person as a flatmate	0.81	0.13	0.68
I would like to be friends with this person	0.83	0.29	0.76
I would like to have interactions like this on daily basis	0.83	0.11	0.69
I would enjoy having other interactions like this	0.79	0.34	0.74
This person is similar to me	0.71	0.16	0.54
This person is knowledgeable	0.60	0.48	0.59
<i>Variance explained</i>	<i>40%</i>	<i>29%</i>	

Note. h² = communality. Loadings on the predominant component are shown in bold.

The final two-component solution accounted for 69% of the variance (Table 8). The first component consisted mostly of items asking whether the participant would like to have similar interactions in the future and items regarding the evaluation of the partner. We termed it the *Future Interactions and Partner* component. The other component consisted of items asking about the evaluation of the current interaction and the evaluation of the partner in terms of warmth and likability. We termed it the *Current Interaction and Likability* component. We

then calculated participants' evaluation for each component in the same way as in Experiment 2.

Although we observed a numerical trend, the imitated participants did not produce higher ratings in the *Current Interaction and Likability* component, as compared to those who were counter-imitated ($M = 6.74$ vs $M = 6.32$; $t(66) = -1.27$, $p = .103$, $d = .31$). Moreover, there was no difference between conditions with regards to the evaluations in the *Future Interactions and Partner* component ($M = 5.13$ vs $M = 5.22$; $t(66) = .24$, $p > .250$, $d = .06$).

We analysed the mean contributions in the Public Goods game. Importantly, the imitated participants contributed more credits to the common pool than participants in the counter-imitation condition ($M = 28.22$ vs $M = 21.59$; $t(66) = -2.95$, $p = .002$, $d = .72$). The imitated group contributed on average about 70% of their credits, whereas the counter-imitated group contributed 54%. This effect was present also when we removed the participants who reported noticing being imitated/counter-imitated during the task ($t(52) = -2.49$, $p = .008$, $d = .68$). We found the same pattern of results for mean contributions on turn one only (see Appendix C).

5.3 Discussion

In Experiment 3, we found that imitating lexical choices in an interactive text chat conversation affected participants' behaviour in the Public Goods game: Participants who were imitated contributed more credits to the common pool, and therefore demonstrated a greater willingness to cooperate with their partner, than participants who were not imitated. However, participants who were imitated did not evaluate their interaction or their partner more positively than those who were counter-imitated.

6 GENERAL DISCUSSION

According to the affiliative goal account of imitation, people imitate each other because it helps them to bond, smoothens their social interactions, and encourages others to cooperate. We investigated whether this is true for linguistic imitation. We asked whether people who were lexically imitated by their conversational partner would produce a more positive evaluation of the interaction and of their partner, and show a greater willingness to cooperate

than those who were counter-imitated. Across three experiments, we found converging evidence that lexical imitation subserves the affiliative goal.

Experiments 1 and 2 provided evidence that when people were lexically imitated, they evaluated the interaction with the imitator more positively. Participants who were imitated during the single word picture-naming task rated the interaction as more smooth (Experiment 1) and produced a more positive evaluation of the current interaction than those who were counter-imitated (Experiment 2). In such a constrained context of a single word exchange, where there was little other information that the participants could use to assess the interaction, our manipulation affected participants' evaluations of the interaction.

Moreover, Experiment 3 provided evidence that lexical imitation can also affect willingness to engage in cooperative behaviour in a subsequent interaction with the same partner. We found that the imitated participants contributed more credits to the common pool in the Public Goods game as compared to those who were counter-imitated. Thus in the much less constrained context of Experiment 3, where participants were allowed to jointly manage their conversational exchange, lexical imitation affected their willingness to cooperate with their partner.

However, our manipulation of lexical imitation did not lead to significant effects on all measures. Surprisingly, we did not find evidence that lexical imitation resulted in a more positive self-reported evaluation of the partner. The imitated participants did not rate their partner as more likeable (Experiment 1) and they did not produce a more positive general evaluation of their partner as compared to the counter-imitated participants (Experiments 2-3). This is in contrast with research in social psychology suggesting that people who imitate the motor behaviour of their partners are rated as more likeable (see Chartrand & Lakin, 2013). However, this effect has not been evidenced equally well with regards to linguistic imitation. Although some researchers have reported similar findings (Manson et al., 2013), other studies have not find a consistent effect on liking (Schoot, Heyselaar, Hagoort, & Segaert, 2016). Our results do not provide support for the hypothesis that interlocutors engage in linguistic imitation in order to be liked or otherwise positively evaluated by others.

In addition, we did not replicate the effect on the evaluation of the interaction in a version of our task where participants were allowed to converse more freely (Experiment 3). This might be due to the fact that when participants were allowed to produce longer utterances, the rich conversational context provided them with other information they could use to assess the interaction. Thus, being imitated or counter-imitated was no longer a salient cue with regards to this evaluation.

Finally, we did not find an effect of imitation (or counter-imitation) during a single word picture-naming task on participants' subsequent behaviour in the PGG (Experiment 2). Nor did we find any difference in the frequency of cooperative decisions in the Stag Hunt game between participants who were imitated and those who were counter-imitated during a single word task (Experiment 1). In previous research on imitation, coordination games have been used with similarly inconsistent results. For example, one study reported that the effect of behavioural imitation on cooperation was observable in only one out of two types of game used in the experiment, suggesting that the occurrence of this effect might depend on the particular type of coordination game used (Verberne et al., 2013). However, some of the studies investigating linguistic imitation failed to find a consistent pattern of results between studies even when using the same game (compare Scissors et al., 2008, with Scissors et al., 2009). Interestingly, studies that demonstrated effects of linguistic imitation on cooperative behaviour used other measures of cooperation (e.g., a negotiation task). Moreover, they also used set-ups where the manipulation was applied during a relatively unconstrained conversation (Fischer-Lokou et al., 2011; Müller et al., 2012; Swaab, Maddux, & Sinaceur, 2011). More work is needed to fully understand under what conditions language imitation increases willingness to cooperate by the person who has been imitated.

The affiliative goal account posits that imitation has both social causes and social consequences. People engage in imitation because they seek positive relations with others, and imitation can help to achieve this goal by fostering social interactions, cooperation, and bonding (Lakin et al., 2003). In the three experiments reported here, we investigated the second part of this claim with regards to linguistic imitation: We tested whether imitating word choice has positive social consequences for the imitator. We found that lexical imitation may result

in a more positive evaluation of the interaction and an increased willingness to cooperate with the partner. But what mechanisms could be responsible for these effects?

Lexical imitation might lead to smoother linguistic interactions, because it helps to reduce the cognitive effort associated with the conversation. Psycholinguistic studies showed that words that had earlier been produced are processed more easily when encountered again. For example, Monsell (1987) found that participants recognised words they had earlier produced more quickly than words they had not seen before. More importantly, Ferreira, Kleinman, Kraljic, and Siu (2012) showed that participants in a collaborative picture naming task responded faster to a word used by their partner if it was the same word that they had produced before. Producing a word primes its representation in the speaker's mental lexicon. This speeds up the subsequent retrieval of the representation and in turn aids language processing when the same word is encountered again (see Barry, Hirsh, Johnston, & Williams, 2001). Lexical imitation taps into this mechanism, and lifts some of the processing effort off the imitated speaker. Crucially, stimuli that are easily processed evoke positive evaluations (Winkielman, Schwarz, Fazendeiro, & Reber, 2003). Thus, a conversation with a partner who imitates one's word choice is likely to be evaluated as more smooth than conversation with a partner who does not imitate.

Consistent with the affiliative goal account, participants who were lexically imitated by their partner showed a greater willingness to cooperate with their partner. It has been proposed that behavioural imitation primes a general prosocial mindset, which in turn makes people more willing to engage in helping and altruistic behaviour towards the imitator, and also more broadly (Ashton-James, van Baaren, Chartrand, Decety, & Karremans, 2007; van Baaren, Holland, Kawakami, & van Knippenberg, 2004). It is possible that linguistic imitation affects behaviour via a similar social priming route. In our experiment, cooperation was directed towards the imitator, but on the basis of previous evidence from imitation studies, we might expect to find such cooperation to be directed towards other people too (e.g., in an economic game involving a third person).

Alternatively, an increased willingness to cooperate in the Public Goods game might have resulted from rational strategizing. Research in experimental economics assumes that

participants' decisions in coordination games are based on the available cues about their interaction partner. For example, people contribute more in coordination games if they believe their partner is likely to cooperate (Dawes, 1980). Interpersonal similarity is another cue that encourages cooperation. People interacting with a partner who is similar to them make more prosocial decisions in a trust game (DeBruine, 2002) and contribute more money in a PGG (Krupp, DeBruine, & Barclay, 2008), as compared to those interacting with a partner that is not similar. Thus, participants who were lexically imitated might have treated the similarity in the word choice as a cue indicating that the other person was likely to cooperate, which in turn encouraged them to do the same (cf. Hommel & Colzato, 2015).

It is not possible with our current design to be certain about whether the effect on cooperative behaviour was driven by the imitation or the counter-imitation condition. However, the former possibility may be more likely, given our results. In Experiment 3, participants in the counter-imitation group contributed on average 54% of the total amount of their credits. This corresponds to a typical contribution in Public Goods games where participants contribute 40-60% (Fehr & Fischbacher, 2003; Ledyard, 1995). Importantly, participants in the imitation group contributed 70% of their credits, which is rather higher than the typical contribution. This pattern is consistent with the prediction that lexical imitation should lead to a greater willingness to cooperate in the imitated partner.

The findings from our three experiments are consistent with the hypothesis that people engage in linguistic imitation to foster their relationships with others. In a design drawing both from psycholinguistics and social psychology, we tested an important assumption of the affiliative goal account: that imitation has positive social consequences for the imitator. We found that lexical imitation led in at least some circumstances to a more positive evaluation of the social interaction and an increased willingness to cooperate with the partner. More generally, our work therefore provides a step towards experimentally controlled investigations of the social function of linguistic imitation.

Chapter 5

Conclusions

1 THESIS SUMMARY

In the opening review chapter, I discussed the current literature that suggests some imitative behaviours might emerge spontaneously, i.e. as a result of automatic mechanisms that operate without intentional control. Moreover, I proposed that such emergent imitation is achieved by some of the mechanisms that contribute to spontaneous interpersonal coordination. I focused on three such mechanisms: simulation, temporal adaptation, and the unconscious goal to affiliate with others. Next, I reviewed the evidence for the automatic involvement of these mechanisms during social interactions, and demonstrated that the research in support of each of these mechanisms tends to focus on a single type of behaviour. Specifically, simulation has been mostly evidenced with regards to simple motor movements, temporal adaptation with regards to continuous rhythmic actions, and the affiliative goal has been shown to regulate the motor behaviours naturally occurring in social interactions. I further argued that it would be fruitful for psychological research on imitation to cross-examine these mechanisms, i.e. investigate whether each could be extended to explain the instances of emergent imitation that are currently outside the scope of interest of its respective research field. I finished the review chapter by discussing some already existing studies that attempted to do that.

In the following empirical chapters, I presented three sets of experiments that aimed to contribute to the effort of cross-examining the mechanisms of emergent imitation. Each chapter focused on a distinct candidate mechanism. In Chapter 2, I presented three experiments that investigated the role of the simulation mechanism in language processing. These studies tested whether the language production system is involved in linguistic prediction during comprehension, as suggested by Pickering and Garrod (2013). I found some evidence in support of this, which suggests that such a simulation mechanism might indeed be routinely engaged during conversations with others. This in turn encourages further research to directly

test the relationship between simulation and the linguistic imitation that spontaneously emerges in natural conversations.

In Chapter 3, I presented three further experiments investigating whether the mechanism of temporal adaptation could explain some instances of imitation that had been observed in joint motor actions. More specifically, these experiments were designed as a follow-up to a recent study by Pfister and colleagues (2013) who found that agents engaged in a discrete non-rhythmic action act faster when imitated by their partner, as compared to counter-imitated. Although the authors interpreted this finding as evidence for a high-level anticipation mechanism, the results obtained from my experiments show that an automatic temporal mechanism is a better explanation: agents act faster when imitated because they adapt to the response pace of their partner (which is faster when the partner is imitating than counter-imitating). This suggests that temporal adaptation might result in spontaneous imitation of some aspects of the observed behaviour also in discrete non-rhythmic actions, which have previously been considered within a framework of high-level representationalist explanations.

Chapter 4 presented three final experiments which focused on exploring the role of the unconscious affiliative goal in emergent linguistic imitation. It has been proposed that behavioural mimicry might be used as a non-conscious tool to create liking and foster social relations between people (Lakin et al., 2003). This hypothesis relies on evidence that imitating the motor behaviour of others during interactions brings about various social benefits, i.e. partners who are imitated tend to positively evaluate the imitator and the interaction with them, and are more likely to cooperate. Thus, such imitation might serve the goal to affiliate with others. In my experiments, I investigated whether linguistic imitation could also be motivated by the affiliative goal. I tested this by manipulating whether people were lexically imitated or counter-imitated and measuring its social effects on the interaction. The results obtained from these experiments suggest that linguistic imitation might help to foster social interactions, and therefore lend some support to the hypothesis that people imitate various aspects of each other's language in order to create affiliation.

In this concluding chapter, I now turn to summarise the findings and discuss some limitations of my experiments. In addition, I propose possible directions for future research. Finally, I

relate my findings to the case for cross-examination that I outlined in the review chapter, and briefly discuss the implications of my work for psychological research on imitation.

2 CONCLUSIONS: INVESTIGATING THE ROLE OF PRODUCTION SYSTEM IN SIMULATION

2.1 Summary of Findings

The three experiments reported in Chapter 2 employed a psycholinguistic paradigm where participants read high- and low-cloze sentence contexts either silently or aloud and responded to a sentence-final stimulus. The type of response varied across the experiments. In Experiment 1, participants were asked to make a lexical decision with regard to the sentence-final stimulus that was either an existing word or a non-word. The lexical decisions and the related response times were recorded. In Experiment 2, they were asked to name the sentence-final stimulus when it was a word (and not name it otherwise). Participants' decision to name (or not to name) was recorded, along with the response time. In Experiment 3, participants named the sentence-final stimulus which was an illustration of the final word of a sentence, and their naming time was recorded.

I hypothesised that if the language production system is routinely used to generate predictions during comprehension, then increasing its engagement (reading aloud vs. silently) should enhance the effects of prediction (high- vs. low-cloze contexts) on language processing. I did not find evidence that engaging the production system influenced the effect of prediction on lexical decisions (Experiment 1) or on decisions to name the sentence-final stimulus (Experiment 2). But importantly, I demonstrated that it enhanced the effect of prediction on participants' spoken response times (Experiments 2-3). This suggests that the production system is indeed involved in generating linguistic predictions, at least in the aspect that is used to facilitate subsequent spoken production.

2.2 Implications

The results obtained from my experiments have some important implications for current research in psychology of language, and for research into linguistic prediction in particular. At

the moment, there are four unresolved questions related to the claim that people predict language (Huettig, 2015). I propose that my findings can contribute to the search for an answer in case of two of these questions, i.e. how is prediction achieved, and why do people predict. First, the results from my experiments are convergent with the idea that the simulation mechanism proposed by Pickering and Garrod (2013) is used for prediction. According to this account, speakers generate predictions by engaging aspects of their production system to simulate the perceived utterance. Such a production-based mechanism could account for the large body of research showing that brain areas and effectors responsible for language production are activated during language comprehension. Second, my results suggest that prediction might be used to prepare one's own subsequent production act. I found that engaging the production system enhanced the effects of prediction only with regard to the fluency of participants' spoken responses. This could be taken as evidence that prediction is particularly useful in natural conversation which requires speakers to quickly and smoothly coordinate their utterances (see Levinson, 2016).

2.3 Limitations and Future Research

Inevitably, the three experiments discussed here have some limitations. First, the engagement of the production system was manipulated by instructing the participants to either read the sentence contexts aloud or silently. In choosing this type of manipulation, I assumed that the activation of the production system could be increased from its default level. By demonstrating that reading aloud resulted in stronger effects of prediction as compared to reading silently, I showed that this assumption might have been correct. Moreover, these findings could be also taken as some evidence for the scalar nature of the activation related to linguistic prediction (cf. DeLong, Urbach, & Kutas, 2005).

However, it could also be argued that reading aloud represents an unusual rather than a typical case of comprehension. If so, then the findings obtained from my experiments would not support the idea that production is routinely engaged to predict during comprehension, but instead demonstrate that it is engaged in this particular case. To address this, one could conduct a study using a different within-subjects manipulation: in the experimental condition, the activation of the language production system could be decreased by applying transcranial

magnetic stimulation (TMS) to the brain areas responsible for language production (left primary motor face area; Watkins et al., 2003), and the effects of prediction on a subsequent production act could be measured using the same task as in Experiment 3. If the effects of prediction were smaller in the experimental, as compared to the control condition (where TMS would be applied to areas responsible for non-linguistic motor action, e.g., left primary motor hand area), then such a study would provide further evidence for the engagement of production during comprehension. Crucially, in conjunction with my current results, it would make a strong case for the routine use of the production system for linguistic prediction.

Future studies could also address the two remaining questions about linguistic prediction that my experiments did not tackle. Specifically, I found that engaging the production system while reading aloud enhanced the aspect of prediction that is useful for producing a subsequent spoken response. But what exactly was the content of this prediction? One likely possibility is that engaging overt production might help to generate phonological predictions about the upcoming word (or at least about its first phoneme). To investigate this, one could employ a similar design as in Experiment 3, but add an additional independent variable: participants could read high- and low-cloze sentence contexts either aloud or silently, and name the sentence-final pictures. Importantly, these pictures would depict either the word that is the most likely continuation of a given sentence, or another word that phonologically overlaps with the first sound of the most likely continuation (cf. Drake & Corley, 2015). This design could also be extended to include a condition where the picture is semantically, but not phonologically related to the most likely continuation. Such a study (or a similar one following this logic) would be able to tease apart the different aspects of the linguistic prediction generated using the simulation mechanism.

Furthermore, future studies could also investigate when people engage this mechanism to predict. It is possible that the production system might be used for prediction especially when processing language in difficult conditions (cf. Adank et al., 2010). In my experiments, I followed this assumption and imposed a processing difficulty by degrading the visibility of the sentence contexts. Would engaging production enhance the effects of prediction also in normal processing? A simple follow-up study could address this question by attempting to replicate the results of Experiment 3 with non-degraded contexts.

3 CONCLUSIONS: INVESTIGATING THE ROLE OF TEMPORAL ADAPTATION IN IMITATION

3.1 Summary of Findings

In the three experiments presented in Chapter 3, I used a joint action paradigm in which pairs of participants engaged in a button-pressing task, where one participant took the role of the leader and another participant took the role of the follower. Participants were seated across a table and each operated a button-box. The leader performed short and long presses in response to cues appearing on a computer screen. The follower was instructed to observe the leader and either make the same (imitation condition) or the opposite press than the leader (counter-imitation condition). In the Replication Experiment, the participants performed the task in this set-up (following the methods of Pfister et al., 2013). Experiment 1 used the same set-up, except there was a divider between the participants so that the leader did not see the follower, and the leader also wore headphones so they did not hear the follower. In Experiment 2, the leader was again able to see and hear the follower as in the Replication Experiment. However, the follower wore headphones and performed their task according to auditory cues that ensured they now acted slower when imitating than when counter-imitating. In all experiments, response times were measured.

These experiments were designed as a follow-up of an original study by Pfister and colleagues (2013) which found that leaders act faster when imitated than counter-imitated by the follower. Across three experiments, I aimed to demonstrate that this finding can be explained by the automatic temporal adaptation mechanism, rather than the high-level co-representation account proposed by the authors. I first replicated this finding using the same methods as the original study (Replication Experiment), and then showed that leaders were no longer faster when imitated than counter-imitated if they were unable to see or hear the follower (Experiment 1). This was consistent with the hypothesis that in the original study leaders spontaneously adapted to their partner's response pace. Finally, I provided even stronger evidence for the critical role of the temporal adaptation mechanism by showing that leaders became slower when imitated than counter-imitated, if their partner was also slower imitating than counter-imitating (Experiment 2).

3.2 Implications

The results obtained from these experiments support the idea that agents' behaviour in social interactions is regulated by the automatic adaptation mechanism, even if agents are engaged in a task that involves discrete non-rhythmic actions. This has implications for research on sensorimotor synchronisation, because it demonstrates that people might attempt to synchronise with others also when engaged in this type of action. Thus, these findings suggest that sensorimotor synchronisation might be more prevalent than previously thought. More specifically, some form of automatic temporal adaptation may operate not only in actions where the goal is to produce a given rhythm or in continuous actions that are subject to the principles of self-organisation, but also in actions that are non-rhythmic and discrete. In turn, this is important for psychological studies that employ paradigms involving such actions, because adaptation is likely to influence the participants' behaviour observed in these studies. For example, research on joint action often uses tasks where two agents perform actions in close proximity. In some of these paradigms, temporal adaptation might be a confounding factor, as I showed with regard to the study by Pfister and colleagues. It is therefore important that researchers wishing to investigate a phenomenon of their choosing in similar joint tasks always consider that the agents' behaviour might be affected by temporal adaptation, or indeed other low-level mechanisms.

3.3 Limitations and Future Research

Although I was able to demonstrate that automatic temporal adaptation shaped the agents' behaviour in this particular task, my experiments face some limitations. First, with the current design I cannot rule the possibility that some variance in participants' behaviour is due to the mechanism proposed by Pfister and colleagues, i.e. that agents anticipate their partner's actions and this facilitates their own actions in the imitation condition. The results obtained from my experiments only show that temporal adaptation plays a more important role in shaping the agents' behaviour than this hypothetical anticipation mechanism. To investigate whether agents engage in anticipation, a follow-up study could manipulate the followers' response times so that they would be constant across the imitation and counter-imitation

condition. If in this case leaders' were significantly faster when imitated than counter-imitated, this could be attributed to anticipation.

Second, using the current paradigm I was not able to show what form of temporal adaptation was at play in this task, i.e. whether the leaders adapted to their partner's response pace due to the automatic phase correction or spontaneous entrainment. One way of discerning between these two possibilities would be to see whether the actions of the interacting agents became temporally coupled in a way consistent with the self-organisation principles (e.g., the Haken-Kelso-Bunz model; Kelso, Delcolle, & Schoner, 1990), which would suggest adaptation was driven by entrainment. However, these principles can be meaningfully applied only to continuously oscillating systems, and therefore they do not lend themselves to the data collected from my experiments. Thus, the fact participants' actions were discrete (i.e., there was an inter-trial interval between each button press) points towards the possibility that adaptation was driven by phase correction. A study using a somewhat similar task could attempt to empirically discern between entrainment and phase correction. For example, a joint continuous tapping paradigm could be used to investigate whether the dynamics of adaptation reflect self-organisation principles or the local phase shifts that are characteristic of phase correction (for a possible paradigm, see Ramenzoni, Sebanz, & Knoblich, 2014).

Future studies should aim to identify other types of social interactions that might be affected by the automatic temporal adaptation mechanism. For example, dialogue could be a fruitful area for such explorations. There is already evidence that some motor behaviours become entrained during conversation (e.g., Fowler et al., 2008). It is less clear, however, whether spoken language could also be affected by temporal adaptation. Speech rate (Webb, 1969) and turn-taking (Wilson & Wilson, 2005) have been suggested to be two possible aspects of speech where temporal adaptation could occur, but to my knowledge there are no controlled experiments that would provide evidence for these claims. One way to investigate whether speakers adapt to their partners' inter-turn intervals (which could be taken as an index of turn-taking, see Beňuš, Gravano, & Hirschberg, 2011) would be to ask two participants to engage in a computer-mediated picture naming task where they would alternate producing spoken utterances. The inter-turn intervals could be then manipulated by gradually adding a lag to the speech of one participant so that it would seem that this participant produces increasingly

longer inter-turn intervals across turns (to provide a baseline, there could also be a control condition where the conversation is left intact). If automatic temporal adaptation regulates turn-taking in spoken dialogue, then both participants should produce longer inter-turn intervals towards the end of the task (and the average interval length should be greater in the manipulated than the intact conversation).

4 CONCLUSIONS: INVESTIGATING THE SOCIAL CONSEQUENCES OF LINGUISTIC IMITATION

4.1 Summary of Findings

The experiments discussed in Chapter 4 used a paradigm drawing both from psycholinguistics and social psychology: pairs of participants engaged in a computerized task where they alternated naming a picture for their partner and responding to their partner naming a picture. Crucially, on some trials their partner named a picture that the participant had already named. The partner's responses on these trials were manipulated between-subjects so that participants in one group saw their partner imitate their earlier word choice (imitation group), whereas participants in the other group saw their partner counter-imitate their word choice (counter-imitation group). After the naming task, participants filled out a questionnaire asking for an evaluation of the interaction and the partner, and played a short decision-making game to measure their willingness to cooperate. Importantly, the picture naming task varied between experiments with regards to the constraints placed on the participants' interaction. In Experiments 1 and 2, participants were instructed to only produce the names for the pictures, whereas in Experiment 3 they were allowed to freely converse over the task within the given time limit.

These experiments set out to investigate the claim that linguistic imitation is motivated by the unconscious goal to affiliate with others, and tested an important assumption of this claim, i.e. that linguistic imitation has positive social consequences. I expected that participants who were lexically imitated by their partner should produce a more positive evaluation of the partner and the interaction, as compared to participants who were counter-imitated. Moreover, participants who were imitated should also be more willing to cooperate with their partner in

the decision-making game, as compared to those who were counter-imitated. Across three experiments, I found some evidence that was convergent with these predictions. Participants who were imitated produced a more positive evaluation of the interaction (Experiments 1-2) and showed a more cooperative behaviour in the decision-making game (Experiment 3), as compared to those who were counter-imitated. However, I found no evidence that being lexically imitated affected the self-reported evaluation of the imitator.

4.2 Implications

The results obtained from these experiments are convergent with the claim that linguistic imitation may be used by the imitators to foster their interaction with others. Participants who were lexically imitated evaluated the interaction more positively and were more willing to cooperate with the imitator, which is consistent with the claim that people use imitation as a “social glue” that helps them to foster their social relations (Lakin et al., 2003). Thus, these findings suggest that linguistic imitation might be motivated by the unconscious goal to affiliate. This is interesting, because it could potentially provide a complementary view to some of the mechanistic explanations that have been proposed to account for linguistic imitation (e.g., Branigan et al., 2000). Should future studies confirm that people imitate each other’s language to satisfy the affiliative goal, some of the currently existing psycholinguistic models of language processing would need to be revised. Furthermore, the findings from my experiments could also be used to illuminate the current accounts of imitation. The fact that the affiliative goal might be involved in imitation of language and of motor behaviours alike could be taken to suggest that it is a more general mechanism, contributing to emergent imitation across different situations and behaviours. Finally, these experiments have some methodological implications. Specifically, both the computerised method of introducing the manipulation (Experiment 3), and the use of the decision-making games to measure cooperative behaviour (Experiments 1-3) offer a more controlled alternative to the methods commonly used in the behavioural mimicry paradigms.

4.3 Limitations and Future Research

Although the results obtained from these three experiments are generally consonant with the predictions made by the affiliative goal account, they are limited in several ways. First, the finding the imitated participants produced a more positive evaluation of the interaction (than the counter-imitated participants) do not fully replicate across experiments. It seems that when participants were allowed to converse more freely, the manipulation did not have a reliable effect on the self-reported evaluation of the interaction. One possibility is that in this rich conversational context being lexically imitated (or counter-imitated) was one of the many cues that participants could use as a basis for their evaluation, and therefore it was not salient enough to elicit the same effect as in the constrained context of single-word exchanges. This possibility could be explored in a study using the same paradigm and procedures as Experiment 3, but involving a greater number of trials on which the manipulation is applied. If such a study would replicate the findings from Experiments 1 and 2, this would suggest that absence of the effect in Experiment 3 can be attributed to the low salience of the manipulation.

Another limitation concerns the findings from the decision-making games. Imitated participants showed a more cooperative behaviour in these games (as compared to counter-imitated participants), but only in the rich conversational context of Experiment 3. It is possible that the difference in the constraints placed on communication is again to be blamed. One possibility is that the rich conversational context provided a naturalistic setting which encouraged participants to treat the observed instances of lexical imitation (or counter-imitation) as a diagnostic cue for the future behaviour of the partner. However, it is unclear why would it encourage them to treat imitation (or counter-imitation) as a cue with regard to the partner's behaviour in the game, but not with regard to their evaluation of the interaction.

Perhaps then the next step should be to replicate these findings. This could be done in a study that would use the same design as Experiment 3, with the exception that it would include an additional baseline group. The procedure in the imitation and counter-imitation groups would be same as before, but in the baseline group the participants would not be subjected to the manipulation. Critically, they would also never see their partners naming the pictures they had already named. This way, participants in the baseline group would not have a chance to

spontaneously imitate or counter-imitate the lexical choices of their partner. Such a study would be interesting as a potential replication of Experiment 3. Moreover, it could help to clarify whether it was indeed imitation that led to more cooperative behaviour. If more cooperative behaviour would be observed in the imitation group than in the other two, this would suggest that imitation promotes cooperation. However, if less cooperative behaviour would be observed in the counter-imitation group as compared to both the baseline and the imitation group, then this would indicate that being lexically counter-imitated leads to a decrease in cooperation.

Future research should also test the hypothesis that linguistic imitation is driven by the goal to affiliate by manipulating the activation of this goal. For example, pairs of participants could engage in a controlled conversational task that would provide them with multiple opportunities to imitate. Prior to the task, participants would be primed either with a goal to affiliate, a goal to disaffiliate, or given a neutral priming (see Lakin & Chartrand, 2003). Next, the amount of linguistic imitation produced in the task would be measured. If an active goal to affiliate does indeed motivate people to imitate the language of their conversational partners, then the highest degree of linguistic imitation should be observed in the group primed with the goal to affiliate, followed by the neutral group, and the lowest degree of imitation should be observed in the group primed to disaffiliate. Such a pattern of results would provide clear evidence for the causal role of the affiliative goal in linguistic imitation.

5 CONCLUSION

To conclude, my studies suggest that psychological research on imitation can be advanced by a systematic cross-examination of the mechanisms that are currently associated with distinct imitative behaviours. In the three sets of experiments presented in this thesis, I was able to show that simulation, temporal adaptation, and the unconscious goal to affiliate are all likely to contribute to emergent imitation. Overall, these findings illuminate our current understanding of imitation in at least three ways.

First, my results are convergent with the idea that some of the mechanisms of emergent imitation contribute to more than one type of imitative behaviour. Specifically, I found evidence that the simulation mechanism might be routinely engaged during language

processing, which in turn gives some credence to the idea that it contributes to linguistic imitation. In addition, previous studies suggest that simulation promotes automatic imitation of motor movements. It is therefore possible that the simulation mechanism might be responsible both for imitation of motor actions and language. Of course, the causal role of simulation for these two imitative behaviours remains to be directly tested. Future studies could investigate it by measuring automatic imitation effects while disrupting the brain areas used for simulation (note that this could be done both for motor movement and language). Should it be confirmed that simulation plays a causal role in imitation across the motor movements and language domains, this would clearly identify it as a domain-general mechanism responsible for emergent imitation.

Second, my findings give some credence to the idea that certain instances of emergent imitation are caused by more than one mechanism. As I argued, linguistic imitation might result from the cognitive simulation mechanism. However, the results from my lexical imitation experiments suggest that it could also be motivated by the goal to affiliate with others. Should further studies confirm the causal involvement of these mechanisms, linguistic imitation could stem from an interplay between the cognitive mechanisms of language processing (i.e. simulation), and the motivational mechanisms that regulate human social life (i.e. the affiliative goal). Subject to future investigations, I propose that these mechanisms are complementary rather than mutually exclusive. One possibility is that the simulation mechanism is modulated by the goal to affiliate with others. This proposition is similar to some recent models of imitation (e.g., Wang & Hamilton, 2012), which I believe should be taken as an encouragement for further research in this direction.

Third, the automatic temporal adaptation mechanism might also contribute to emergent imitation by helping to effortlessly coordinate actions in time. My results show that temporal adaptation can lead agents to adopt the response pace of their interaction partner. It is likely that the tendency to fall into the same rhythm with others provides a scaffolding for coordinating other aspects of actions. Moreover, it is possible that temporal adaptation works in conjunction with the simulation and the affiliative goal mechanism. With regards to linguistic imitation, temporal adaptation could be responsible for copying the temporal aspects of the perceived utterance (e.g., speech rate), whereas simulation could promote copying other

aspects (e.g., lexical and syntactic choices, phonetic features). The level of engagement of these two cognitive mechanisms could be then modulated by the motivation to affiliate with the conversational partner. More work is needed to estimate whether such an account of emergent linguistic imitation could be true.

Together, the empirical studies presented in this thesis support the view that agents might spontaneously imitate each other due to certain cognitive mechanisms, and that imitation might at times be motivated by its positive social consequences. Future research should continue to explore the overlap between the different cognitive and motivational mechanisms of emergent imitation. Only this way over a century of empirical efforts will eventually yield models capable of explaining the richness and complexity of human imitation.

Appendix

Appendix A: Investigating the Role of Production System in Simulation

1 D-PRIME ANALYSES

For Experiments 1 and 2, we also assessed variation in participants' sensitivity through a d-prime analysis. We conducted a 2 (Predictability: high- vs low-cloze) X 2 (Reading Type: aloud vs silently) X 2 (Reading Type Order: aloud first vs silently first) mixed-ANOVA.

1.1 Experiments 1 and 2

See Table S1 for the d-prime means, and Table S2 for the ANOVA results from Experiments 1 and 2.

Table S1

Experiments 1 and 2: Mean d-prime values by Predictability and Reading Type

Experiment 1		
Predictability	Reading Type	
	reading silently	reading aloud
high cloze	1.36	1.56
low cloze	1.19	1.31
Experiment 2		
Predictability	Reading Type	
	reading silently	reading aloud
high cloze	1.31	1.21
low cloze	1.20	1.23

Table S2

Experiments 1 and 2: ANOVA results

Experiment 1			
	$F(1,22)$	p	η^2_G
Predictability	4.63	.043	.04
Reading Type	2.44	.133	.02
Reading Type Order	.66	>.250	.01
Predictability * Reading Type	.24	>.250	<.01
Predictability * Reading Type Order	1.80	.193	.01
Reading Type * Reading Type Order	<.01	>.250	<.01
Predictability * Reading Type * Reading Type Order	.07	>.250	<.01
Experiment 2			
	$F(1,30)$	p	η^2_G
Predictability	.15	>.250	<.01
Reading Type	.14	>.250	<.01
Reading Type Order	3.20	.084	.06
Predictability * Reading Type	.49	>.250	<.01
Predictability * Reading Type Order	.10	>.250	<.01
Reading Type * Reading Type Order	6.94	.013	<.03
Predictability * Reading Type * Reading Type Order	.11	>.250	<.01

2 LIKELIHOOD OF A “WORD” RESPONSE (GLMM)**2.1 Model Description**

In Experiments 1-2, the measurement of whether participants made a “word” response or not yielded a binary variable. Following the good practices in the field, we therefore ran a binomial GLMM to calculate the likelihood of a “word” response across conditions (Jaeger, 2008). Models were computed using R v.3.0.3 (lme4 package v.1.1-5; Bates, Maechler, Bolker, & Walker, 2015). To help convergence, prior to running the model we centered and scaled the predictors, and specified an increased number of evaluations in the model syntax. The maximal-structure model did not converge, so we changed the model optimizer, and then

proceeded to simplify by removing interactions from the random-effects structure (starting from the highest-order interaction).

2.2 Experiment 1

For the final model reported in the paper, we retained the full fixed-effects structure and the two-way interactions in random structure, but removed the three-way interaction and forced independence between random effects. See the code below for the syntax of the model:

```
glmer (WordResponse ~ 1 + Predictability * Reading Type * Item Type * Reading Type Order  
+ (1 + Item Type + Predictability + Reading Type + Item Type : Predictability + Item Type :  
Reading Type + Predictability : Reading Type || Participant) + (1 | Item), data = imi, family =  
binomial, control = glmerControl (optCtrl = list(maxfun = 1e5), optimizer = "bobyqa"))
```

2.3 Experiment 2

For the final model reported in the paper, we retained the full fixed-effects structure, but forced independence between random effects. Model syntax:

```
glmer (WordResponse ~ 1 + Predictability * Reading Type * Item Type * Reading Type Order  
+ (1 + Predictability * Reading Type * Item Type || Participant) + (1 | Item), data = imi, family  
= binomial, control = glmerControl(optimizer = "bobyqa", optCtrl = list(maxfun = 1e5)))
```

3 RESPONSE TIMES (LME)

3.1 Model Description

In Experiments 1-3, we applied contrasts to the predictors and ran a maximal version of the LME model with an increased number of evaluations (lme4 package v.1.1-5). The following sections present the syntax used for the models reported in the paper. Furthermore, they present the results from these models, including additional analyses carried out on different subsets of the full dataset. Note that these analyses yield converging results.

3.2 Experiment 1

See Table S3 and S4 for results. Syntax for the LME model used in Experiment 1:

```
lmer (RT ~ Predictability * Item Type * Reading Type * Reading Type Order + (1 + Predictability * Item Type * Reading Type | Participant) + (1 | Item), data=imila, control = lmerControl (optCtrl = list(maxfun = 1e5)))
```

Table S3

Experiment 1: Results from LME model on participants' RT on the dataset excluding outliers

Experiment 1			
	<i>B</i>	<i>SE</i>	<i>t</i>
Intercept	1124.58	64.90	17.32
Predictability	177.76	27.37	6.49
Item Type	-214.12	39.14	-5.47
Reading Type	-259.00	55.87	-4.64
Reading Type Order	95.45	129.55	.74
Predictability * Item Type	31.70	45.19	.70
Predictability * Reading Type	-30.14	40.73	-.74
Item Type * Reading Type	-95.29	50.80	-1.88
Predictability * Reading Type Order	97.01	52.22	1.86
Item Type * Reading Type Order	-68.73	76.55	-.90
Reading Type * Reading Type Order	287.81	111.73	2.58
Predictability * Item Type * Reading Type	-21.05	77.33	-.27
Predictability * Item Type * Reading Type Order	-114.36	84.20	-1.36
Predictability * Reading Type * Reading Type Order	-112.11	81.39	-1.38
Item Type * Reading Type * Reading Type Order	23.53	101.54	.23
Predictability * Item Type * Reading Type * Reading Type Order	178.80	154.53	1.16

Table S4

Experiment 1: Results from LME model on participants' RT on the dataset excluding outliers and error trials

Experiment 1			
	<i>B</i>	<i>SE</i>	<i>t</i>
Intercept	1102.78	58.78	18.76
Predictability	174.91	26.68	6.56
Item Type	-294.91	52.60	-5.61
Reading Type	-258.60	57.58	-4.49
Reading Type Order	72.52	117.22	.619
Predictability * Item Type	54.19	51.95	1.04
Predictability * Reading Type	-20.41	46.36	-.44
Item Type * Reading Type	-173.02	64.46	-2.68
Predictability * Reading Type Order	57.72	50.27	1.15
Item Type * Reading Type Order	-151.99	103.67	-1.47
Reading Type * Reading Type Order	328.05	115.15	2.85
Predictability * Item Type * Reading Type	-85.35	91.45	-.93
Predictability * Item Type * Reading Type Order	-174.10	97.55	-1.78
Predictability * Reading Type * Reading Type Order	-52.62	92.68	-.57
Item Type * Reading Type * Reading Type Order	12.83	128.88	.10
Predictability * Item Type * Reading Type * Reading Type Order	228.46	182.84	1.25

3.3 Experiment 2

The syntax for the LME model reported in the paper:

```
lmer (RT ~ Predictability * Reading Type * Reading Type Order + (1 + Predictability * Reading Type | Participant) + (1 | Item), data=imi4, control = lmerControl (optCtrl = list(maxfun = 1e5)))
```

Tables S5 and S6 show results from additional LME models that were carried out on the dataset including both the word (where participants were supposed to speak) and non-word items (where any spoken responses are erroneous). See below for the syntax for these models:

lmer (RT ~ Predictability * Item Type * Reading Type * Reading Type Order + (1 + Predictability * Item Type * Reading Type | Participant) + (1 | Item), data=imi4, control = lmerControl (optCtrl = list(maxfun = 1e5)))

Table S5

Experiment 2: Results from LME model on participants' RT on the dataset excluding outliers

Experiment 2			
	<i>B</i>	<i>SE</i>	<i>t</i>
Intercept	767.565	14.051	54.63
Predictability	47.118	16.244	2.90
Item Type	37.081	22.205	1.67
Reading Type	110.367	24.737	4.46
Reading Type Order	35.035	28.102	1.25
Predictability * Item Type	27.639	27.812	0.99
Predictability * Reading Type	-92.187	26.913	-3.43
Item Type * Reading Type	202.616	28.205	7.18
Predictability * Reading Type Order	-4.188	32.487	-0.13
Item Type * Reading Type Order	52.147	44.410	1.17
Reading Type * Reading Type Order	5.145	49.474	0.10
Predictability * Item Type * Reading Type	126.477	56.552	2.24
Predictability * Item Type * Reading Type Order	-5.061	55.625	-.09
Predictability * Reading Type * Reading Type Order	2.863	53.827	0.05
Item Type * Reading Type * Reading Type Order	77.266	56.410	1.37
Predictability * Item Type * Reading Type * Reading Type Order	94.010	113.103	0.83

Table S6

Experiment 2: Results from LME model on participants' RT on the dataset excluding outliers and the trials where participants were still reading the context after the onset of the recording

Experiment 2			
	<i>B</i>	<i>SE</i>	<i>t</i>
Intercept	757.19	15.94	47.51
Predictability	60.94	16.68	3.65
Item Type	37.65	23.73	1.59
Reading Type	131.16	26.72	4.91
Reading Type Order	39.67	31.88	1.24
Predictability * Item Type	47.11	33.37	1.41
Predictability * Reading Type	-119.25	29.81	-4.00
Item Type * Reading Type	200.23	31.15	6.43
Predictability * Reading Type Order	-7.02	33.35	-.21
Item Type * Reading Type Order	65.84	47.44	1.39
Reading Type * Reading Type Order	.80	53.44	.02
Predictability * Item Type * Reading Type	87.05	60.92	1.43
Predictability * Item Type * Reading Type Order	.24	66.75	.00
Predictability * Reading Type * Reading Type Order	22.14	59.61	.37
Item Type * Reading Type * Reading Type Order	45.97	62.30	.74
Predictability * Item Type * Reading Type * Reading Type Order	51.3906	121.8415	0.42

3.4 Experiment 3

In addition to the analysis reported in the paper, another LME model was carried out on a bigger subset of the full dataset. See Table S7 for the results. See below for the syntax for the LME models in Experiment 3:

```
lmer (RT ~ Predictability * Reading Type * Reading Type Order + (1 + Predictability * Reading Type | Participant) + (1 | Item), data=imi4, control = lmerControl (optCtrl = list(maxfun = 1e5)))
```


Table S7

Experiment 3: Results from LME model on participants' RT on the dataset excluding outliers, but with retained trials where participants were still reading the context after the onset of the recording

Experiment 3			
	<i>B</i>	<i>SE</i>	<i>t</i>
Intercept	504.32	24.68	20.43
Predictability	125.58	26.20	4.79
Reading Type	105.59	20.03	5.27
Reading Type Order	16.81	44.18	.38
Predictability * Reading Type	-55.35	17.19	-3.22
Predictability * Reading Type Order	16.31	28.41	.57
Reading Type * Reading Type Order	68.70	40.06	1.71
Predictability * Reading Type * Reading Type Order	-13.73	34.35	-.40

4 ATTENTION QUESTIONS (GLME)

To probe whether participants attended to the sentence contexts, we analysed the likelihood of producing a correct answer in response to the yes/no questions. For Experiments 1-3, we ran a binomial Generalized Linear Mixed Model with Predictability, and Reading Type as fixed effects and by-subjects random intercepts and slopes to test the likelihood of giving a correct answer for each design cell. See Table S8 for the mean percentages of corrects responses, and Table S9 for the results from the models.

4.1 Model Description

Prior to running the models, we centered and scaled the predictors. We then ran GLMMs with an increased number of evaluations, and a non-default optimizer specified in the model syntax:

```
glmer (correct ~ 1 + Predictability * Reading Type + (1 + Predictability * Reading Type | Participant), data = imi7, family = binomial, control=glmerControl (optCtrl = list(maxfun = 1e5, optimizer = "bobyqa"))
```

4.2 Experiments 1, 2, and 3

Table S8

Experiments 1-3: Percentages of correct responses to the yes/no questions by Predictability and Reading Type

Experiment 1		
	Reading Type	
Predictability	reading silently	reading aloud
high cloze	26%	26%
low cloze	24%	24%
Experiment 2		
	Reading Type	
Predictability	reading silently	reading aloud
high cloze	26%	27%
low cloze	23%	24%
Experiment 3		
	Reading Type	
Predictability	reading silently	reading aloud
high cloze	27%	30%
low cloze	20%	23%

Table S9

Experiments 1-3: GLMM analyses of the likelihood of a correct response to the yes/no question. Table shows results from the fixed effects structure

Experiment 1				
	<i>B</i>	<i>SE</i>	<i>z</i>	<i>p</i>
Intercept	2.29	.15	14.76	< .001
Predictability	.24	.15	1.64	.101
Reading Type	.01	.13	.07	> .250
Predictability * Reading Type	.01	.14	.05	> .250
Experiment 2				
	<i>B</i>	<i>SE</i>	<i>z</i>	<i>p</i>
Intercept	1.83	.13	13.98	< .001

Predictability	.10	.09	1.15	> .250
Reading Type	.18	.09	1.97	.046
Predictability * Reading Type	-.02	.09	-.21	> .250

Experiment 3

	<i>B</i>	<i>SE</i>	<i>z</i>	<i>p</i>
Intercept	2.31	.35	6.63	< .001
Predictability	.74	.27	2.70	.007
Reading Type	.06	.28	.23	> .250
Predictability * Reading Type	.04	.28	.13	> .250

Appendix

Appendix B: Investigating the Role of Automatic Temporal Adaptation in Imitation

1 REPLICATION EXPERIMENT

1.1 Methods

Based on the sample size chosen by Pfister et al. (2013), we invited 24 previously unacquainted participants (18 female, 6 male; right-handed; same-gender pairs). Participants were Edinburgh University students with no motor disorders and were paid £6. The study was approved by the local ethics committee and consent was obtained from all participants. We used the same procedure and materials as in our Experiment 1. However, similarly to the original study (Pfister et al., 2013), there was no divider and participants could see and hear each other while doing the task (Figure 3).

1.2 Results

Warm-up trials, error trials (4.31%) and outliers (2.25%) were removed prior to analysing the leader's responses. Error trials for both participants (8.65%), as well as further outliers (1.45%) were removed prior to the follower's analyses.

We found that followers' responses were facilitated in the imitation condition (Figure S1, panel c): Followers were significantly faster in imitation than counter-imitation ($M = 325$ ms vs $M = 447$ ms; $t(23) = 6.71$, $p < .001$, $r = .81$, 95% CI = [84, 159]). In follow-up pairwise comparisons, we then tested whether this effect was present for both long and short key presses. After excluding one follower who showed an extremely high error rate (48.94%) for long presses in imitation, we found that the imitation facilitation effect was present for both

long ($M = 307$ ms vs $M = 370$ ms; $t(22) = 3.54$, $p = .002$, $r = .60$, 95% CI = [26, 100]) and short leader presses ($M = 333$ ms vs $M = 495$ ms; $t(22) = 6.20$, $p < .001$, $r = .80$, 95% CI = [108, 216]).

Importantly, we replicated the original finding that leaders were faster in imitation than counter-imitation ($M = 415$ ms vs $M = 436$ ms; $t(23) = 3.22$, $p = .004$, $r = .56$, 95% CI = [8, 37]) (Figure S1, panel c). Pairwise comparisons showed this difference was significant both for long ($M = 426$ ms vs $M = 444$ ms; $t(23) = 2.46$, $p = .022$, $r = .46$, 95% CI = [3, 33]) and short presses ($M = 405$ ms vs $M = 427$ ms; $t(23) = 3.24$, $p = .004$, $r = .56$, 95% CI = [9, 39]).

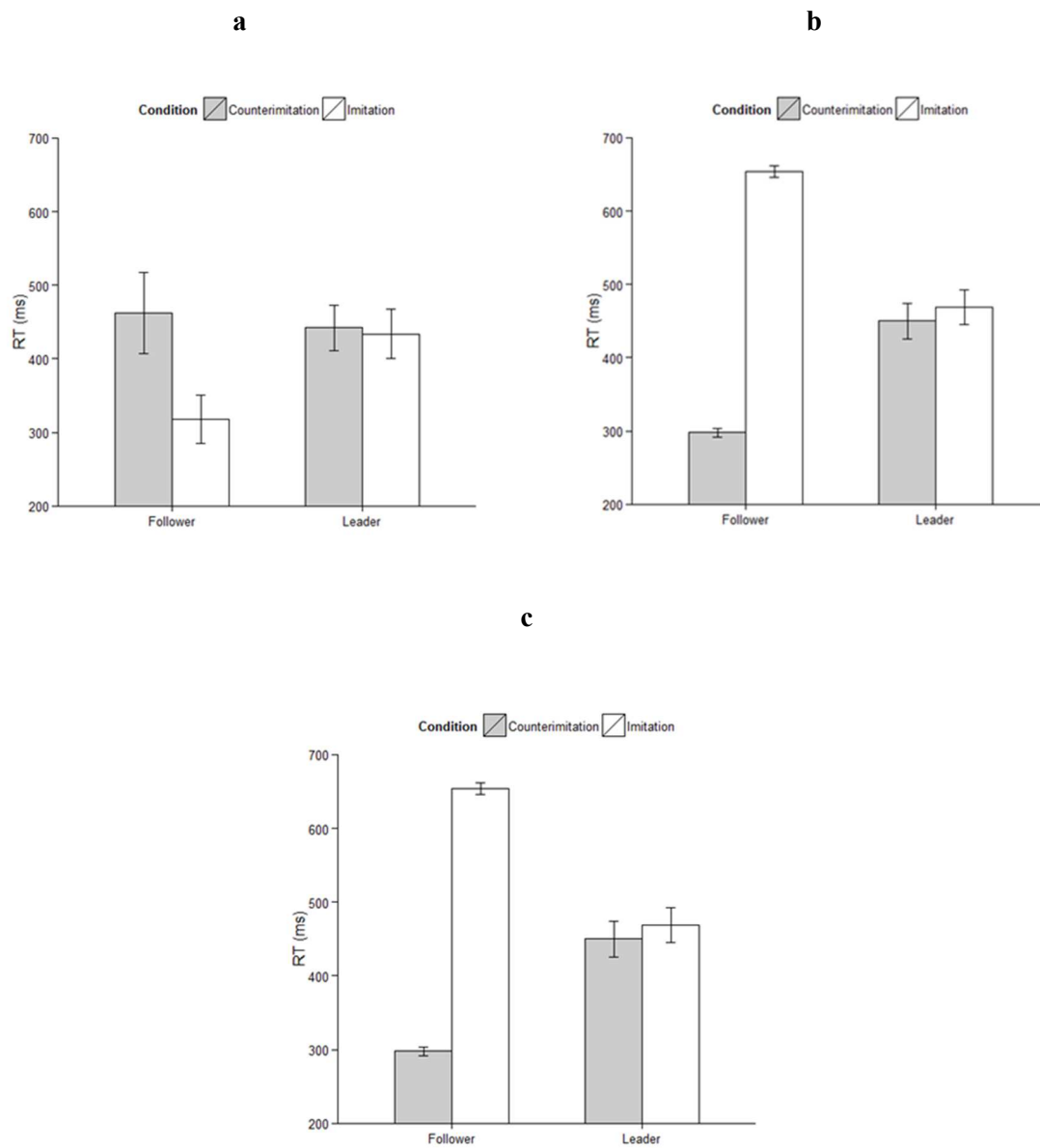


Figure S1. Mean leaders' and followers' RT in imitation and counter-imitation, in Experiment 1, Experiment 2 and Replication. Error bars represent 95% CI. Panel a shows Experiment 1, panel b Experiment 2, and panel c Replication. Panels a and b correspond to Figure 3 and 4 (respectively) in the main paper.

2 ERROR RATE

2.1 Experiment 1

A 2 (Condition) X 2 (Leader's Press Type) within-subjects ANOVA on arcsine-transformed percentage scores showed that leader's error trials were equally distributed between conditions and press types, (Leader's Press Type: $F(1,23) = 1.42$, $p = .245$, $\eta_G^2 = .03$; Condition: $F(1,23) = .38$, $p > .250$, $\eta_G^2 < .01$; interaction: $F(1,23) = .40$, $p > .250$, $\eta_G^2 < .01$). Similarly, there were no significant effects on followers' error rate (Leader's Press Type: $F(1,23) = 1.15$, $p > .250$, $\eta_G^2 < .01$; Condition: $F(1,23) = 0.01$, $p > .250$, $\eta_G^2 < .01$; interaction: $F(1,23) < .001$, $p > .250$, $\eta_G^2 < .01$).

2.2 Experiment 2

We found no significant effects on leaders' error rate (Leader's Press Type: $F(1,47) = 3.45$, $p = .069$, $\eta_G^2 = .03$; Condition: $F(1,47) = .06$, $p > .250$, $\eta_G^2 < .01$; interaction: $F(1,47) = .94$, $p > .250$, $\eta_G^2 < .01$). However, there was a significant main effect of condition on followers' error rate, indicating that followers made more errors in counter-imitation than imitation (16.97% vs 11.94%; $F(1,47) = 5.69$, $p = .021$, $\eta_G^2 = .02$). No other effects were significant (Leader's Press Type: $F(1,47) = .22$, $p > .250$, $\eta_G^2 < .01$; interaction $F(1,47) = .73$, $p > .250$, $\eta_G^2 < .01$).

A possible worry is that leaders might have been affected by the followers' error rate in counter-imitation. There are two reasons to dismiss this possibility: (a) leaders did not show a corresponding difference in the distribution of error rates and (b) had leaders experienced difficulties due to followers' high error rate in counter-imitation, they would have slowed down; instead, they sped up in counter-imitation, adapting to followers' RT.

2.3 Replication Experiment

Leaders' error trials were equally distributed between conditions and press types (Leader's Press Type: $F(1,23) = .15$, $p > .250$, $\eta_G^2 < .01$; Condition: $F(1,23) = .16$, $p > .250$, $\eta_G^2 < .01$; interaction: $F(1,23) = .54$, $p > .250$, $\eta_G^2 < .01$). We found no significant effects for followers' error rate (Leader's Press Type: $F(1,23) = .03$, $p > .250$, $\eta_G^2 < .01$; Condition: $F(1,23) = 0.12$, $p > .250$, $\eta_G^2 < .01$; interaction: $F(1,23) = .16$, $p > .250$, $\eta_G^2 < .01$).

3 ADDITIONAL ANALYSES (ANOVA)

3.1 Experiment 1

Table S10

Experiment 1: Followers' and leaders' average response times (RT) by Leader's Press Type and Condition

Condition	Followers' RT		Leaders' RT	
	Leader's Press Type		Leader's Press Type	
	short	long	short	long
imitation	328	308	425	444
counter-imitation	526	392	440	443

Note. Average RT were calculated for data excluding followers' and leaders' error trials and outliers (see the main paper for details). Response times are reported in *ms*.

We ran a 2 (Condition: imitation vs counter-imitation) X 2 (Leader's Press Type: short vs long) within-subjects ANOVA on followers' RT. The analysis revealed main effects of Condition ($F(1,23) = 34.21$, $p < .001$, $\eta_G^2 = .27$) and Leader's Press Type ($F(1,23) = 12.02$, $p = .002$, $\eta_G^2 = .07$), qualified by a significant interaction ($F(1,23) = 14.42$, $p < .001$, $\eta_G^2 = .05$). Followers were faster in imitation than counter-imitation, and the difference between conditions was bigger for short than for long presses (Table S10).

We conducted a similar analysis on leaders' RT and found an interaction between Condition and Leader's Press Type ($F(1,23) = 5.67$, $p = .026$, $\eta_G^2 < .01$). Importantly, pairwise comparisons showed that this interaction was not driven by the effect of Condition (see the

tests reported in the main paper). Instead, it appeared to be driven by a significant difference in leaders' RT between short and long presses in the imitation condition ($t(23) = 2.92, p = .008, r = .52, 95\% \text{ CI} = [6, 34]$; Table S10). There was no such difference in counter-imitation ($t(23) = 0.47, p > .250, r = .10, 95\% \text{ CI} = [-14, 23]$). We found no main effects of Condition ($F(1,23) = 1.32, p > .250, \eta_G^2 < .01$) or Leader's Press Type ($F(1,23) = 2.77, p = .109, \eta_G^2 < .01$).

3.2 Experiment 2

Table S11

Experiment 2: Followers' and leaders' average response times (RT) by Leader's Press Type and Condition

Condition	Followers' RT		Leaders' RT	
	Leader's Press Type		Leader's Press Type	
	short	long	short	long
imitation	781	533	459	481
counter-imitation	310	286	439	462

Note. Average RT were calculated for data excluding followers' and leaders' error trials and outliers (see the main paper for details). Response times are reported in *ms*.

A 2 (Condition: imitation vs counter-imitation) X 2 (Leader's Press Type: short vs long) within-subjects ANOVA on followers' RT found a main effect of Condition ($F(1,47) = 298.11, p < .001, \eta_G^2 = .61$) and a main effect of Leader's Press Type ($F(1,47) = 132.57, p < .001, \eta_G^2 = .17$). Furthermore, there was a significant interaction suggesting that followers were slower in imitation as compared to counter-imitation, and that this difference was greater for short than for long leader presses ($F(1,47) = 110.64, p < .001, \eta_G^2 = .12$; Table S11).

With regards to leaders' RT, the analysis confirmed that leaders were slower in the imitation than in the counter-imitation condition ($F(1,47) = 8.96, p = .004, \eta_G^2 = .01$). Moreover, there was a main effect of Leader's Press Type on leaders' RT, suggesting that leaders responded faster for short than long presses ($F(1,47) = 21.70, p < .001, \eta_G^2 = .02$). The interaction was not significant ($F(1,47) = 0.10, p > .250, \eta_G^2 < .01$).

3.3 Replication Experiment

Table S12

Replication experiment: Followers' and leaders' average response times (RT) by Leader's Press Type and Condition

Condition	Followers' RT		Leaders' RT	
	Leader's Press Type		Leader's Press Type	
	short	long	short	long
imitation	332	311	405	426
counter-imitation	485	361	427	444

Note. Average RT were calculated for data excluding followers' and leaders' error trials and outliers (see the main paper for details). In addition, followers' RT were calculated on data excluding one participant who showed an extremely high error rate. Response times are reported in *ms*.

The analysis on followers' RT revealed main effects of Condition ($F(1,22) = 42.26, p < .001, \eta_G^2 = .16$) and Leader's Press Type ($F(1,22) = 11.84, p = .002, \eta_G^2 = .08$), qualified by a significant interaction ($F(1,22) = 12.30, p = .002, \eta_G^2 = .03$). Followers were faster in imitation than counter-imitation, and the difference between conditions was bigger for short than for long presses (Table S12).²⁰

Leaders' RT were shorter in imitation than counter-imitation condition ($F(1,23) = 9.35, p = .006, \eta_G^2 = .01$) and shorter for short than long leader presses ($F(1,23) = 7.62, p = .011, \eta_G^2 = .01$; Table S12). The interaction between Condition and Leader's Press Type was not significant ($F(1,23) = 1.36, p = .250, \eta_G^2 < .01$).

²⁰ Prior to ANOVA on the follower's RT's, we removed data from one participant due to an extremely high error rate (see Results from the Replication experiment).

4 CROSS-CORRELATION ANALYSIS

In order to further investigate the relationship between the leader's RT on the current trial and the follower's RT on the preceding trial, we conducted a cross-correlation analysis (maximum lag of 1) on the data from all three experiments. We assumed that the time-series of participant responses obtained in our task had local stationarity and performed the analysis in non-overlapping windows of 6 observations (cf. Konvalinka et al., 2010).

For each dyad, we calculated average cross-correlation coefficient for lag = -1 (estimates a correlation between the leader's RT on the current trial and the follower's RT on the preceding trial), lag = 0 (leader's RT on the current trial and the follower's RT on the current trial) and lag = 1 (leader's RT on the current trial and the follower's RT on the following trial). Average coefficients were then transformed into Fischer Z-scores and entered into a one-way MANOVA with Experiment as a between-subjects factor (Experiment: Experiment 1 vs Experiment 2 vs Replication) and average coefficients for lags -1, 0, and 1 as the dependent variables.

Table S13

Experiments 1-2 and Replication experiment: Average Z-transformed cross-correlation coefficients for lags -1, 0, and 1

	Lag		
	-1	0	1
Experiment 1	0.003	-0.083	0.023
Experiment 2	0.057	-0.259	0.040
Replication	0.064	-0.084	0.022

If the condition effect on leaders' RT is due to temporal anticipation (i.e., leaders anticipate followers' response speed on the current trial), we would expect to see a positive correlation for lag 0. Instead, we observed negative correlations for lag 0 in all experiments, suggesting that temporal anticipation did not affect leader's action execution on the current trial (Table S13). In addition, the correlation was stronger in Experiment 2 than in Experiment 1 and the Replication experiment, as indicated by the MANOVA (main effect of Experiment: $F(2,45) = 9.68, p < .001$) and follow-up pairwise comparisons (Experiment 2 vs 1: $t(23.35) = 3.48, p = .002, d = .87, 95\% \text{ CI} = [.07, .28]$; Experiment 2 vs Replication: $t(28.53) = 3.97, p < .001, d =$

.99, 95% CI = [.08, .26]; Experiment 1 vs Replication: $t(20.93) = .01, p > .250, d = .00$, 95% CI = [-.11, .11]). A strong negative correlation in Experiment 2 is likely to be a consequence of the fact that the followers responded to the auditory cue and not directly to leaders' actions. However, a negative relationship in Experiment 1 and in the Replication experiment could suggest that followers dynamically adapted to leader's RT (e.g., if the leader was particular slow on a given trial, the follower could compensate by speeding up their own response).²¹

If leaders adapt to followers' RT on the preceding trial, we would expect a positive correlation for lag -1, but only in the experiments where participants could observe each other. Consistently with this prediction, there was a weak positive correlation in Experiment 2 and the Replication experiment, but a null correlation in Experiment 1 (Table S13). This numerical trend was reflected by a main effect of Experiment in MANOVA ($F(2,45) = 3.74, p = .031$). Furthermore, follow-up pairwise comparisons revealed that Experiment 2 differed significantly from Experiment 1 in terms of correlation strength for lag -1 ($t(22.93) = -2.95, p = .007, d = .74$, 95% CI = [-.09, -.02]). Similarly, there was a difference between the Replication experiment and Experiment 1, however it was only marginally significant ($t(17.98) = -2.12, p = .048, d = .61$, 95% CI = [-.12, .00]). Experiment 2 and Replication did not differ ($t(15.41) = 0.25, p > .250, d = .06$, 95% CI = [-.05, .06]). We found no effect of Experiment with regards to correlation coefficients for lag 1 ($F(2,45) = .34, p > .250$).

²¹ Note that this argument is purely speculative, as our experiments were not designed to test adaptation on the side of the follower.

5 TRIAL-BY-TRIAL RELATIONSHIP BETWEEN FOLLOWER'S AND LEADER'S RT

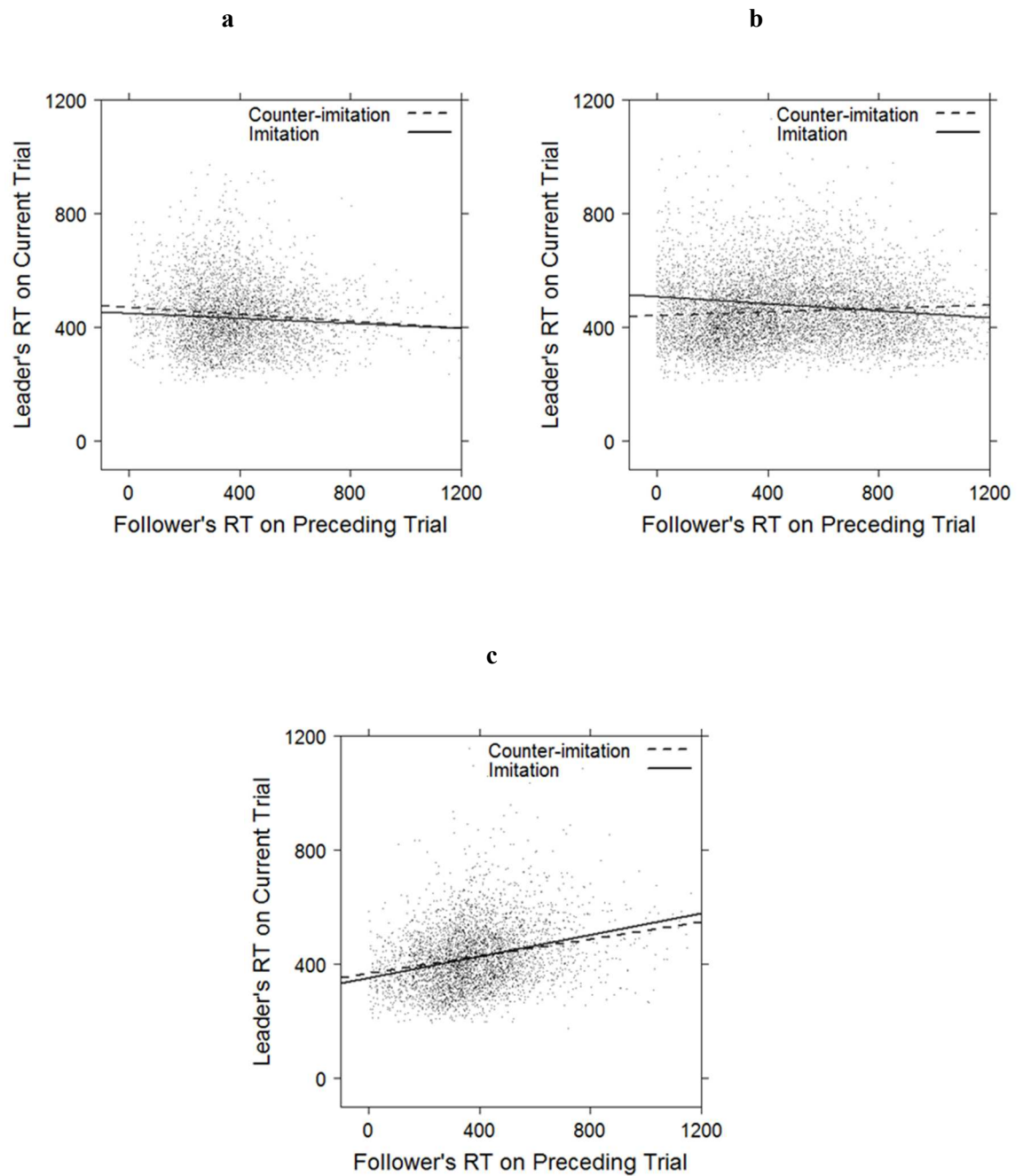


Figure S2. Relationship between Follower's RT on preceding trial and Leader's RT on current trial. Lines represent regression lines for imitation (solid) and counter-imitation (dashed). Panel a shows Experiment 1, panel b Experiment 2, and panel c Replication experiment.

6 MAIN ANALYSES ON DATA INCLUDING OUTLIERS

We checked whether outlier rejection affected the key results in Experiments 1-2 and the Replication experiment. For each experiment, we ran the analyses on the data excluding the leader and follower error trials, but retaining the outliers.

6.1 Experiment 1

We obtained the same pattern of results as in the analyses on the data without outliers. Followers were significantly faster in imitation than counter-imitation ($M = 188$ ms vs $M = 384$ ms; $t(23) = 6.17, p < .001, r = .79$, 95% CI = [139, 279]), and this effect was present both for long ($M = 46$ ms vs $M = 235$ ms; $t(23) = 4.22, p < .001, r = .66$, 95% CI = [94, 275]) and short leader presses ($M = 333$ ms vs $M = 536$ ms; $t(23) = 7.70, p < .001, r = .85$, 95% CI = [152, 264]). Leaders showed no difference in response speed between imitation and counter-imitation ($M = 442$ ms vs $M = 449$ ms; $t(23) = 1.07, p > .250, r = .22$, 95% CI = [-6, 19]). Follow-up comparisons showed there was no difference between conditions both for long ($M = 453$ ms vs $M = 452$ ms; $t(23) = -.03, p > .250, r = .01$, 95% CI = [-13, 13]) and short presses ($M = 431$ ms vs $M = 445$ ms; $t(23) = 1.61, p = .121, r = .32$, 95% CI = [-4, 30]).

6.2 Experiment 2

Again, we obtained the same pattern of results as for the data without outliers. Followers responded slower in imitation than counter-imitation ($M = 657$ ms vs $M = 307$ ms; $t(47) = -16.10, p < .001, r = .92$, 95% CI = [-397, -309]), both for long ($M = 531$ ms vs $M = 290$ ms; $t(47) = -10.24, p < .001, r = .83$, 95% CI = [-294, -198]) and short leader presses ($M = 788$ ms vs $M = 322$ ms; $t(47) = -21.13, p < .001, r = .95$, 95% CI = [-509, -420]). Similarly, leaders were significantly slower in imitation than counter-imitation ($M = 478$ ms vs $M = 458$ ms; $t(47) = -3.11, p = .003, r = .41$, 95% CI = [-32, -7]), and this difference was significant both for long ($M = 490$ ms vs $M = 470$ ms; $t(47) = -3.01, p = .004, r = .40$, 95% CI = [-32, -6]) and short presses ($M = 467$ ms vs $M = 446$ ms; $t(47) = -2.89, p = .006, r = .39$, 95% CI = [-34, -6]).

6.3 Replication Experiment

As in the analyses on the data without outliers, followers were faster in imitation than counter-imitation ($M = 331$ ms vs $M = 439$ ms; $t(23) = 6.65$, $p < .001$, $r = .81$, 95% CI = [83, 158]), and this effect was significant both for long ($M = 315$ ms vs $M = 364$ ms; $t(22) = 3.28$, $p = .003$, $r = .57$, 95% CI = [22, 100]) and short leader presses ($M = 339$ ms vs $M = 490$ ms; $t(22) = 6.39$, $p < .001$, $r = .81$, 95% CI = [109, 213]).²²

Consistently with the analyses on the data without outliers, leaders were significantly faster in imitation than counter-imitation ($M = 421$ ms vs $M = 446$ ms; $t(23) = 3.54$, $p = .002$, $r = .59$, 95% CI = [10, 39]). However, pairwise comparisons found that this effect was significant only for short presses ($M = 411$ ms vs $M = 439$ ms; $t(23) = 3.45$, $p = .002$, $r = .58$, 95% CI = [-34, -6]), but not for long presses ($M = 435$ ms vs $M = 452$ ms; $t(23) = 2.05$, $p = .052$, $r = .39$, 95% CI = [-.12, 31]).

²² Prior to the pairwise comparisons for the follower's RT's, we removed data from the participant who had extremely high error rate.

Appendix

Appendix C: Investigating the Social Consequences of Linguistic Imitation

1 CONTRIBUTIONS IN THE PGG ON TURN ONE

Both in case of Experiment 2 and Experiment 3, the analysis of participants' contributions on turn one yielded the same pattern of results as the analysis of participants' contributions averaged across all six turns. In Experiment 2, we compared the mean contributions on turn one between the imitation and counter-imitation condition using a Mann-Whitney test (data were not normally distributed). There was no difference between contributions in imitation and counter-imitation ($M = 22.81$ vs $M = 22.62$; $W = 444$, $p > .250$, $r = -.08$). In Experiment 3, participants in the imitation condition contributed significantly more than participants in the counter-imitation condition ($M = 27.94$ vs $M = 21.44$; $W = 390$, $p = .009$, $r = -.31$).

2 MATERIALS

2.1 Short Questionnaire

Please complete this brief questionnaire regarding your participation in the experiment. This questionnaire is anonymous, so please <u>do not</u> sign this sheet. For each question circle the number that represents your answer most closely. Please don't hesitate to use the whole scale (1-9).										
1. How clear would you say were the instructions in the experiment?										
1	2	3	4	5	6	7	8	9		
extremely obscure					extremely clear					
2. How difficult was the task?										
1	2	3	4	5	6	7	8	9		
extremely easy					extremely difficult					
3. How likable was the other participant?										
1	2	3	4	5	6	7	8	9		
extremely dislikeable					extremely likable					

4. How recognisable were the entities on the pictures?									
1	2	3	4	5	6	7	8	9	
extremely ambiguous							extremely recognisable		
5. How similar were the pictures to each other?									
1	2	3	4	5	6	7	8	9	
extremely dissimilar							extremely similar		
6. How familiar were the entities on the pictures?									
1	2	3	4	5	6	7	8	9	
extremely rare							extremely familiar		
7. How smoothly would you say your interaction went with the other participant?									
1	2	3	4	5	6	7	8	9	
extremely awkward							extremely smooth		
8. How interesting was the task?									
1	2	3	4	5	6	7	8	9	
extremely boring							extremely interesting		
9. How well did the network connection work?									
1	2	3	4	5	6	7	8	9	
extremely bad							extremely good		
10. How satisfied are you with your performance in the experiment?									
1	2	3	4	5	6	7	8	9	
extremely dissatisfied							extremely satisfied		

2.2 Multi-item Questionnaire: Full Item List

1. I would ask this person for advice*
2. This interaction was satisfying
3. This person is knowledgeable*
4. This person is warm*
5. This interaction was pleasant
6. This person is likeable*
7. I would rate this level of rapport as high
8. This person is approachable*
9. I would like this person as a coworker*
10. I would like to have interactions like this on daily basis
11. I would like this person as a flatmate*
12. This interaction made me feel at ease
13. This person is friendly*
14. I would enjoy having other interactions like this
15. I would like to be friends with this person*
16. This person is similar to me*
17. This person is physically attractive*

* Items from the Reysen Liking Scale.

2.3 Instructions for the Picture Naming Task

You will be playing an object naming and object matching game with a partner over a network connection. You will see pairs of pictures. You will take it in turns to name objects and match objects to a name. When it is your partner's turn to name, the programme will display the name they provided below the pictures. Your task is to select the appropriate picture using the arrow keys (LEFT or RIGHT). When it is your turn to name, you will see instructions telling you which picture to name. Your task then is to type the name of the object in the chat box provided. Please type in a single word whenever possible, e.g., "cat" instead of "a cat" or "a cute little cat". Please do your best to avoid any spelling mistakes. If you are ready to start the game, please call the experimenter.

2.4 Instructions for the Picture Naming Task

You will be playing an object naming and object matching game with a partner over a network connection. You will communicate using a simple chat client. You will each see a grid with four pictures. Both you and your partner will see the same pictures, but their positions in the grid will be random and therefore may be different for you and your partner. You will take it in turns to name pictures and match pictures to a name. When it is your partner's turn to name, the program will highlight one picture in their grid. Your partner then will tell you the name of the picture and where it is located in their grid. You will respond by telling your partner where this picture is located in your grid using the chat client. If it happens to be the same place as in your partner's grid, you will type in snap instead.

When it is your turn to name, the program will highlight one picture in your grid. You will use the chat client to tell your partner the name of the picture and where it is positioned in your grid, (e.g., I have a crocodile in cell 1). Your partner will respond by telling you where it is in their grid (or saying snap if it is in the same place as in yours). When typing, please take your time to type accurately and correct any spelling mistakes. The game will move on to the next turn automatically after 30 seconds. If you are ready to start the game, please call the experimenter.

2.5 Instructions for Stag Hunt Game

This is almost the end of the study. You already earned your reward for participation. Now you have a chance to win some additional money. You will be playing the Forest Hunt game with the other participant. The rules are very simple:

There are two hunters in the forest, you and the other player. There are two types of animals you can hunt: (1) hare - is worth £1, easy to hunt; you can do it on your own; (2) stag - is worth £4, very hard to hunt; two hunters are needed to shoot it.

Each hunter can shoot only once. If you choose to hunt for the hare, you are guaranteed to hunt it down. You get £1 that will be added to your total earnings for the experiment. If you choose to hunt for the stag and the other player does so too, you successfully hunt it down and split £4 between you. In this case £2 will be added to your earnings. However, if one hunter chooses to shoot the stag, but another hunter goes for the hare, the one that goes for the hare earns £1, but the one that goes for the stag is left with nothing. Press SPACEBAR whenever you are ready to play the game.

2.6 Instructions for Public Goods Game

“This is almost the end of the study. You already earned your reward for participation. Now you have a chance to win some additional money. You and the other player will be playing the Investment game. The rules are very simple:

There are two investors, you and the other player. When the turn starts, each of you is given 40 credits. You can use any amount of these credits to invest into a common pool. Whatever you decide to keep, stays with you. Whatever is invested into the pool gets multiplied by some factor (e.g., 1.5) and then divided between the two players. You will be told each turn what the multiplying factor is for that turn. For example, if player A keeps 20 credits and invests the other 20 and player B does the same, the outcome of the turn for player A will be:

in the pool 20 (from player A) + 20 (from player B) = 40 credits

$40 \times 1.5 = 60$

$60/2 = 30$

player A kept 20 and earned 30 from the pool

at the end of the turn player A has 50 credits

This example is just one of the many possible outcomes in this game. Please spend a minute thinking about other possible scenarios. There is one more thing you need to know: the decisions are blind, i.e., you won't know how much the other player invested until the end of the study. At the end of the study we will pick one turn at random, and you will be paid real money according to how many credits you had when that turn ended. Each credit is worth 5p. The maximum possible payoff in this game is £4.60. Please call the experimenter when you are ready to play the game.

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